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EMME/2
SYSTEM APPLICATIONS IN SHANGHAI TRANSIT SYSTEM - A CASE STUDY

by

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ABSTRACT

The transit system in Shanghai is playing a leading role in transporting people from one place to another. The operation conditions of the system is getting more and more complicated. A comprehensive analysis of the system is accomplished with the help of the EMME/2 system in terms of its demand, supply and their interactions. A "vicious circle" is seen in the downtown area. Based on this analysis, an alternative bus line is suggested for the improvement of the current transit system. The simulated results indicate that there is not only a significant improvement in the transit service, but also a significant reduction of congestion, thus providing better traffic conditions in the downtown area.

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RÉSUMÉ

Le système de transport de la ville de Shanghai joue un rôle majeur pour les déplacements des personnes d'un endroit à un autre. Mais, de plus en plus, ce système rencontre différents problèmes au niveau de ses conditions d'opération. À l'aide du système EMME/2, une analyse globale est faite pour étudier l'offre, la demande, de même que leurs interactions. Nous pouvons constater l'existence d'un "cercle vicieux" au centre-ville. En se basant sur cette analyse, nous proposons d'ajouter une autre ligne d'autobus de façon à améliorer le réseau de transport déjà mis en place. Les résultats simulés nous révèlent qu'en plus d'observer une nette amélioration au niveau de l'opération du système de transport, on remarque une diminution significative de la congestion au centre-ville, ce qui a pour effet d'y améliorer les conditions de la circulation.

1. INTRODUCTION

Shanghai is the largest city in China with a population of 12 million people and covering an area of six thousand km^2, and is renowned as the commercial and industrial center in the country.

In Shanghai, there are three major travel modes: transit, bicycle and pedestrian. Of these modes, the transit mode accounts for 70% of the total trips. Therefore, the transit system is playing a leading role for transporting people from one place to another.

Shanghai Transit Company is one of the largest transit companies in the world consisting of 5,000 buses and 50,000 employees making 11 million trips daily with nearly 200 different bus lines. The ferry, another kind of complementary means of transporting people from the Pu Dong (浦东) area to the downtown area or vice versa across the Wang Pu (黄浦) River, is in no competition with the buses for passengers.

Due to the rapid growth of the economic and social activities, there is an increase in transportation whereby transit problems such as long travel time and congestion in the city arise. In order to solve these problems, a task force has been established to carry out a long-median-short term comprehensive transportation planning. Our study consists of a basic work to lead the transit system in a proper direction.

It is very important, at the transportation planning level, to use a transportation planning system as a crucial aid to the planners in both understanding the problems and providing all kinds of necessary suggestions. It is now widely known that the EMME/2 system developed at the Centre de recherche sur les transports (C.R.T.) at the Universitē de Montréal can serve as the best system to fulfill our needs due to its multi-modes, four-steps, exceptional graphic display and interactive functions. All other systems available on the market are not as competitive. Last but not least, most advanced technologies developed in the

transportation theory have been fully absorbed in the system which makes its computation much faster.

This paper is organized as follows: in Section 2, a brief introduction is made to EMME/2; Section 3 describes the objectives of the study and basic data requirements; Section 4 presents a more detailed description of the current transit system by observing at its demand, supply and their interactions; Section 5 is devoted to a full discussion of a possible improvement on the current system. Section 6 presents the conclusion of this paper.

2. EMME/2 SYSTEM

EMME/2 is a zonally based aggregated demand system capable of making trip generations, trip distributions, mode splits and assignments for both transit and auto. The system features interactive color graphics, providing the planners with a visual representation of activity patterns and allowing simple but necessary changes to the EMME/2 data base. This feature is unique and makes EMME/2 much easier to use than the traditional transportation planning systems.

The nature of the specific work limits our discussions to the issues of interest in the transit areas (EMME/2 can achieve much more than what is described in this paper). There are three major basic data required for EMME/2: highway network, transit network and transit matrix.

Highway network (Figure 2.1) is defined as a set of zones where transit trips are originated and destinated, a set of nodes considered as road intersections or bus stops and a set of auxiliary and highway links connecting those zones and nodes. Transit network (or "transit line") is a set of lines represented by different nodes which are defined as a sequence of nodes with specific conditions allowed at each node (e.g. boarding or non-boarding time) and layover time at two terminals. The transit matrix for the system is typically a matrix of zonally aggregated OD pairs, ideally generated by a survey or trip demand model.

A scenario consists of a base highway network and a corresponding set of transit network that when combined, describes a distinct transportation supply arrangement. EMME/2 permits several scenarios to be developed simultaneously and be used for comparative analysis. Figure 2.2 summarizes the data bank of the EMME/2 system.

The EMME/2 system adopts an optimal strategy or hyperpath method to assign trips of the transit OD matrix onto the transit network so that the passengers flow in the network and service levels for all the nodes, links

and transit network. The assignment of the transit trips is obtained by a generalized cost inducing four variables : a) auxiliary time - e.g. walking time - b) boarding time, c) waiting time, and d) in-vehicle time.

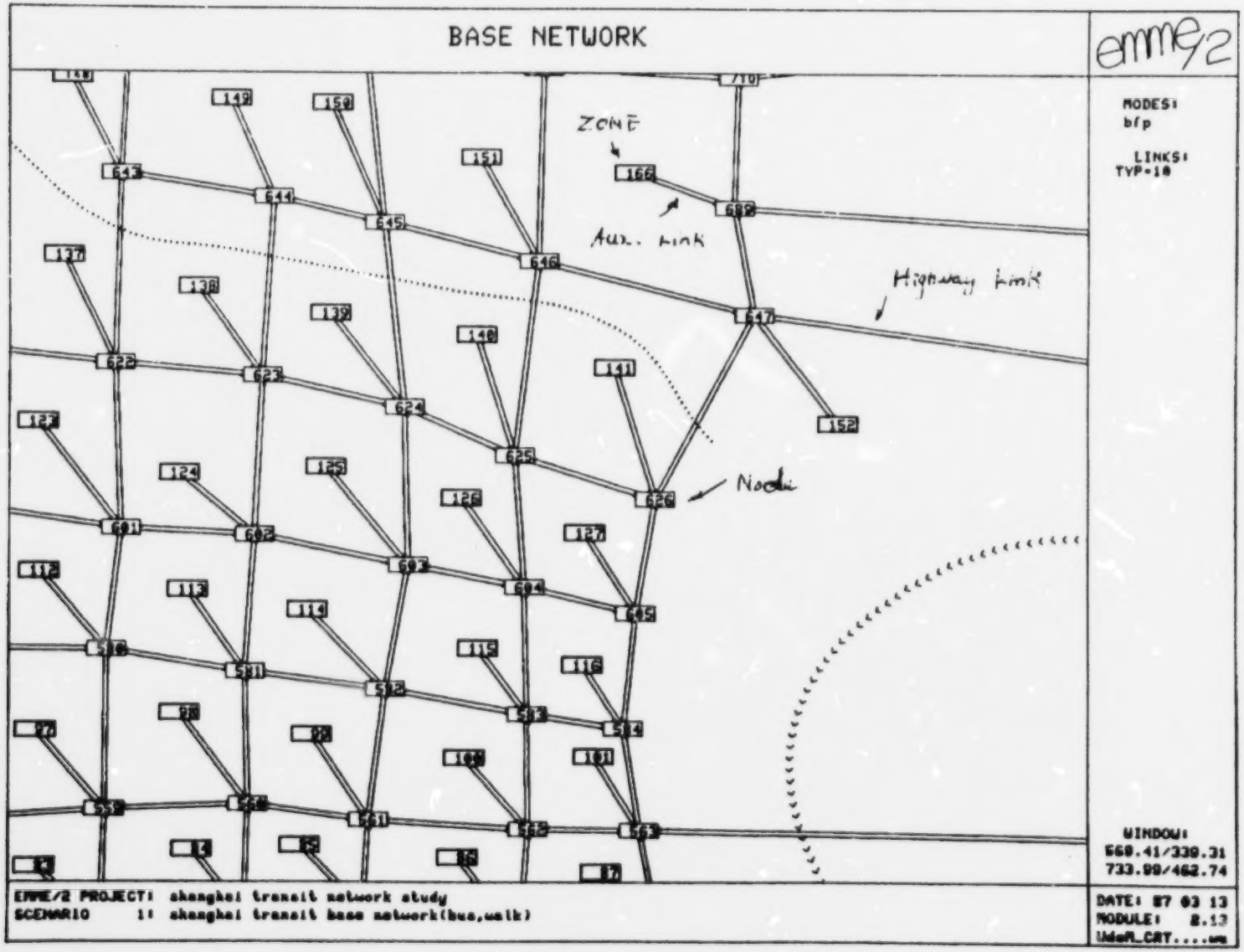

Figure 2.1 : Highway Network

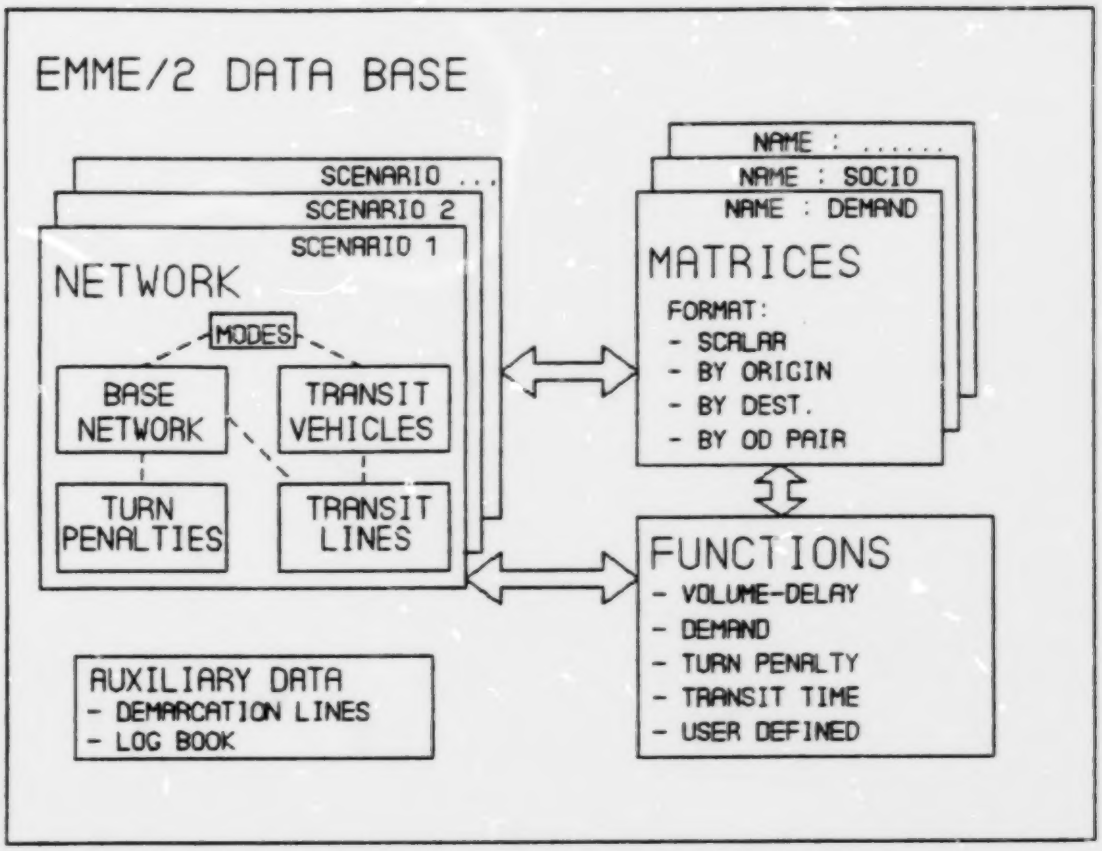

Figure 2.2 : Data Bank

3. OBJECTIVES AND BASIC DATA REQUIREMENTS

3.1 Objectives

The main objectives are to analyse the current transit system in Shanghai and determine key implications in its improvement so that we will be able to present a serie of suggestions for the Shanghai Comprehensive Transportation Planning. The scope of this study is subject to the urban area covering 300 km^2 with considerations of short term improvements. The whole set of data for the analysis was taken from a previous work entitled "Monthly-Ticket-Survey" in 1982.

3.2 Highway network

The highway network used is in fact an aggregated network, representing only these links passed by transit links, whereby there are 316 zones, 319 nodes, 1668 links with a total length of 1120,36 km. It is assumed that all the auxiliary links are equal to 250 m at a speed of 4,5 km/h. This assumption could be adjusted if necessary. The highway network is shown in Figure 3.1.

For later explanations of convenience, the whole network is divided into 16 areas (as shown in Figure 3.2) expressed in terms of GB1, GB2,..., GB16. Table 3.1 gives a brief description of these areas.

Table 3.1 : Area description

area GB#	description	area GB#	description
1	suburban	9	industrial
2	residential and industrial	10	residential, industrial
3	residential and industrial (Pu Dong)	11	suburban
4	industrial (Pu Dong)	12	suburban
5	residential, business, shopping, downtown Bund	13	industrial
6	industrial, shopping, business	14	a little industrial
7	suburban	15	suburban
8	large industrial	16	suburban

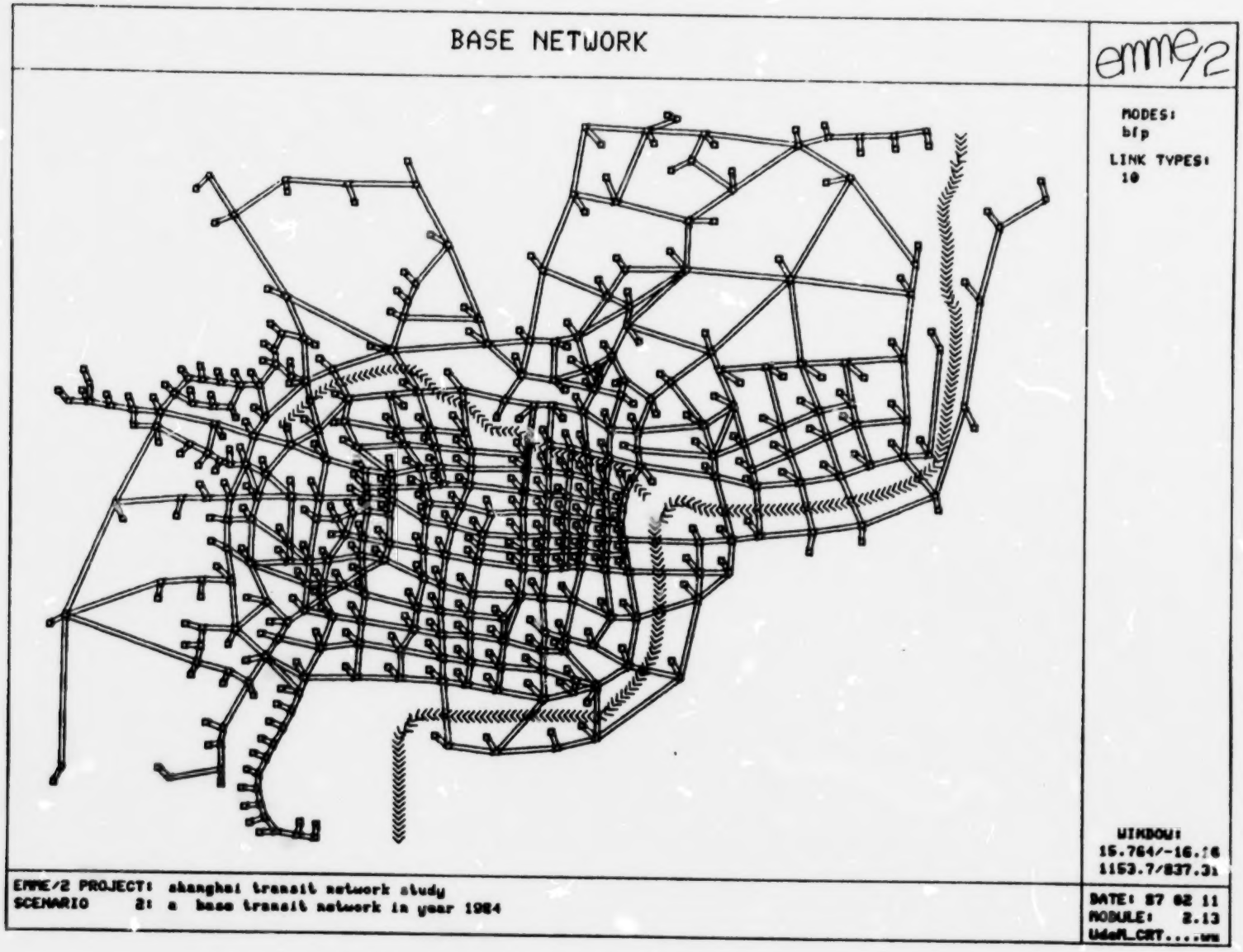

Figure 3.1 : Highway network in Shanghai

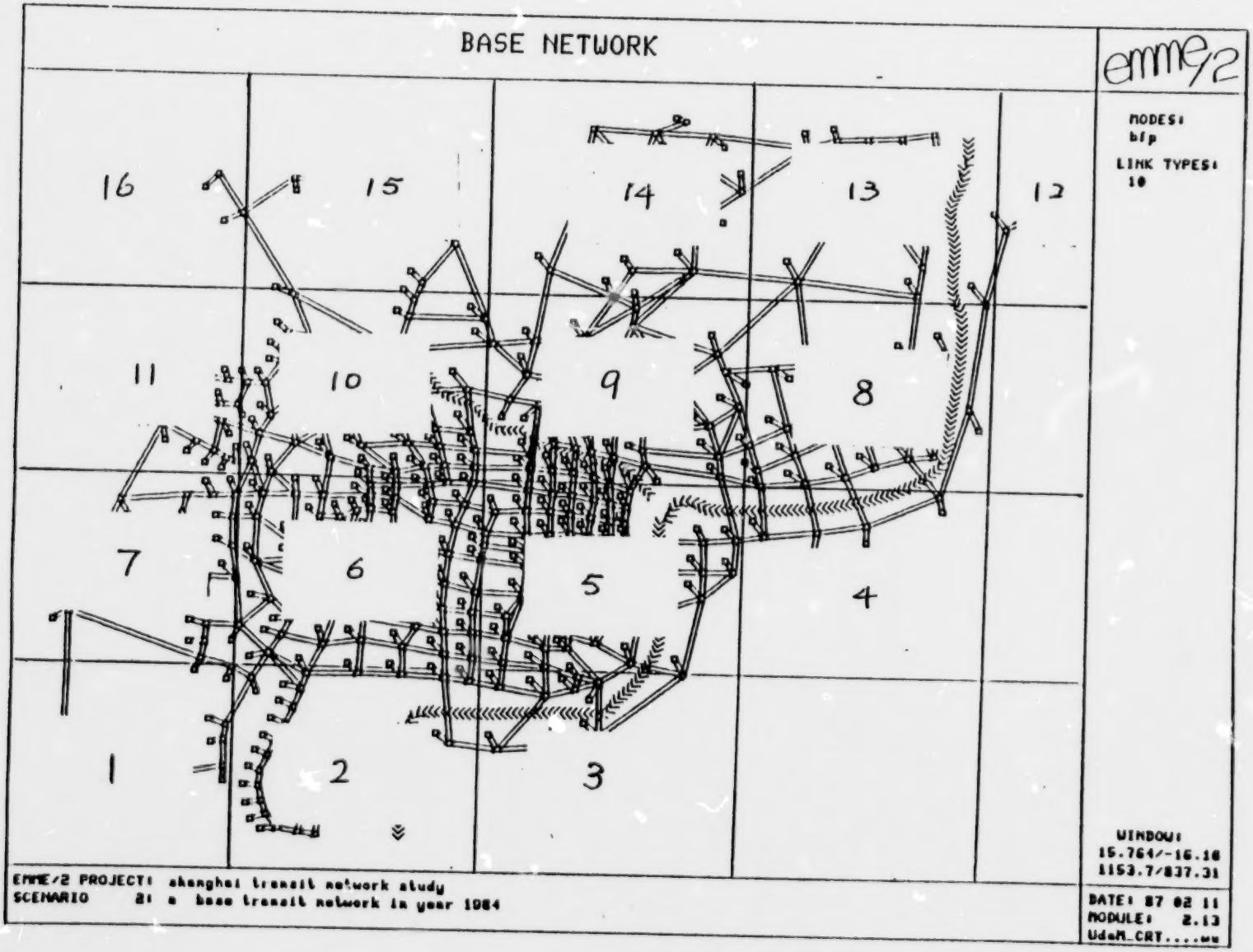

Figure 3.2 : The total network is divided into 13 areas

3.3 Transit network

The transit network is also quite aggregated in the sense that some express bus lines are integrated into the corresponding regular bus lines and the headways for different bus lines are fixed for the whole day with an average of 3 min., and the speed for all the bus lines is 14 km/h. There are 98 bus lines and 12 ferries as shown in Figure 3.3.

3.4 Transit OD matrix

The transit OD matrix was establised based on a large-scale survey entitled "Shanghai Monthly Ticket Survey" conducted in 1982. Monthly-ticket holders were surveyed on their origins, destination and other necessary information such as travel paths from an origin to a destination in terms of bus lines. Therefore, this OD matrix possesses the following characteristics: 1) most of trips from the matrix for home-based-work or home-based-business purposes; 2) these trips are trips with a distance larger than other purpose trips; 3) unknown beginning time of travel, i.e. those trips taken at different times of the day, and 4) those trips represent a majority of the total trips, especially at rush hour. We believe that it is more than reasonable to use these properties, for the analysis of the travel pattern, travel time and transfers, etc. The results of these data are also worthwhile to consider. This survey indicated 1 263 936 trips including 1 260 248 interzonal trips, and an average of 1,19 transfers and 36,20 min. for in-vehicle time.

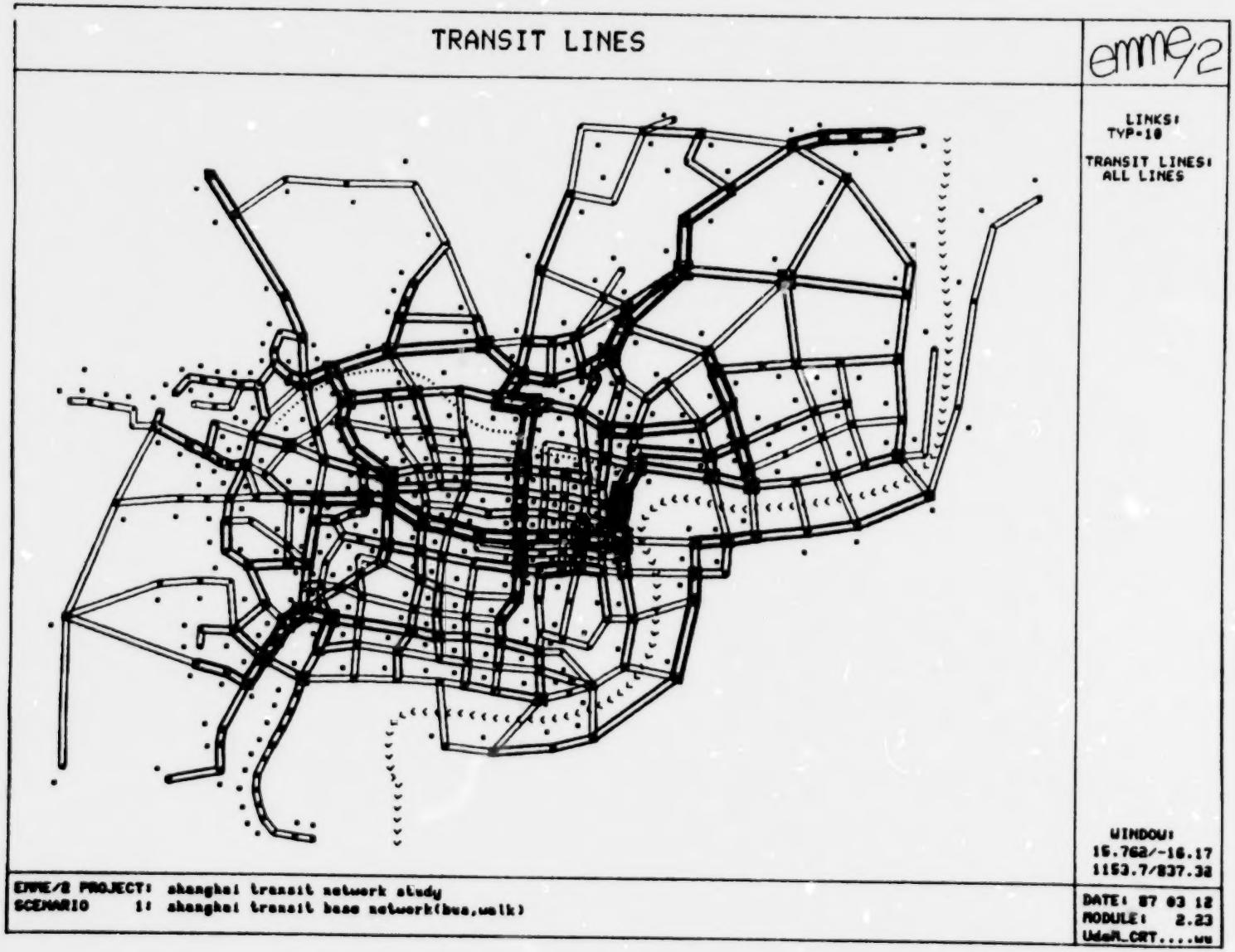

Figure 3.3 : Transit network in Shanghai

4. CURRENT TRANSIT SYSTEM DESCRIPTIONS

In this section, a more detailed description of the current transit system is presented besides the context in 1.1, which is classified into demand, supply and travel pattern influenced by the demand and supply.

4.1 Transit OD demand

The transit OD demand analysis is done in the hope of understanding some large total origin and total destination trips (in short, O and D trips) as well as large OD pairs to show the major OD spatial or desire flow direction (not effected by the current transit network) called the OD trip pattern.

4.1.1 Large O and D trips

It is difficult to notice every O and D trips for all zones. A constraint matrix is used to display only these O and D larger than certain limits. Figure 4.1 shows all zones with total O trips generated. It is trivial to verify that there are quite that many zones in areas such as GB6 and GB10, and some in GB5, but not many in GB8 and GB9.

Figure 4.2 shows all destination zones with total D trips attracted. A general idea is obtained: a few such zones are in the downtown area such as GB5, but a lot are in areas such as GB9 and GB8.

By comparing these two figures, we can see that large O trip zones are more clustered around the downtown area such as GB10, GB6 and GB5, while the D trip zones are more diversified in GB8, GB9, GB5.

Figures 4.3 and 4.4 therefore justify the conclusion where only those zones are shown with their total O and D larger than 250 accounting for 16,8% of total trips.

4.1.2 Large OD pairs

By the same token, a constraint matrix is used for displaying those OD pairs such that the OD trips for the pairs are larger than certain predetermined values.

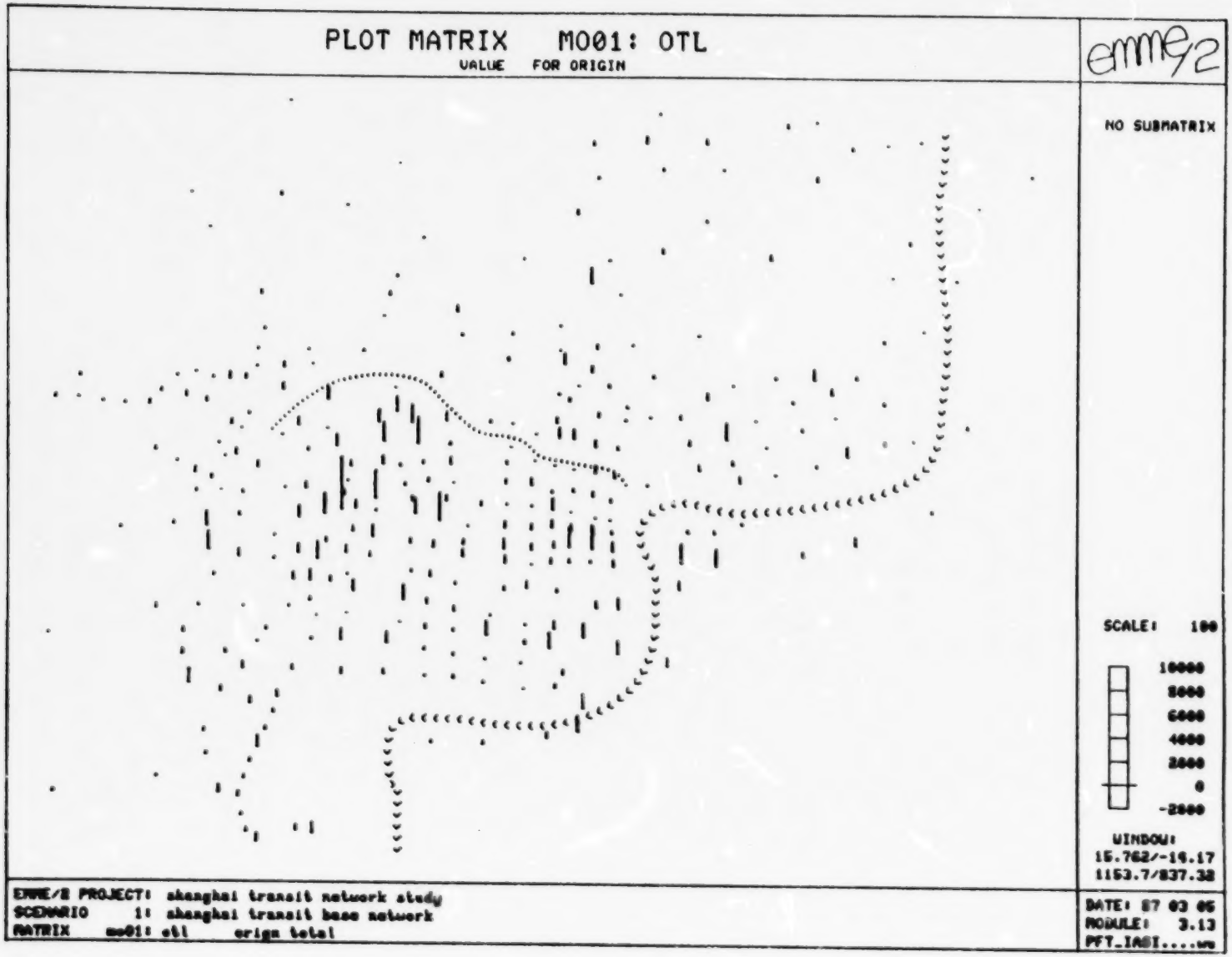

Figure 4.1 : Total O trip distribution

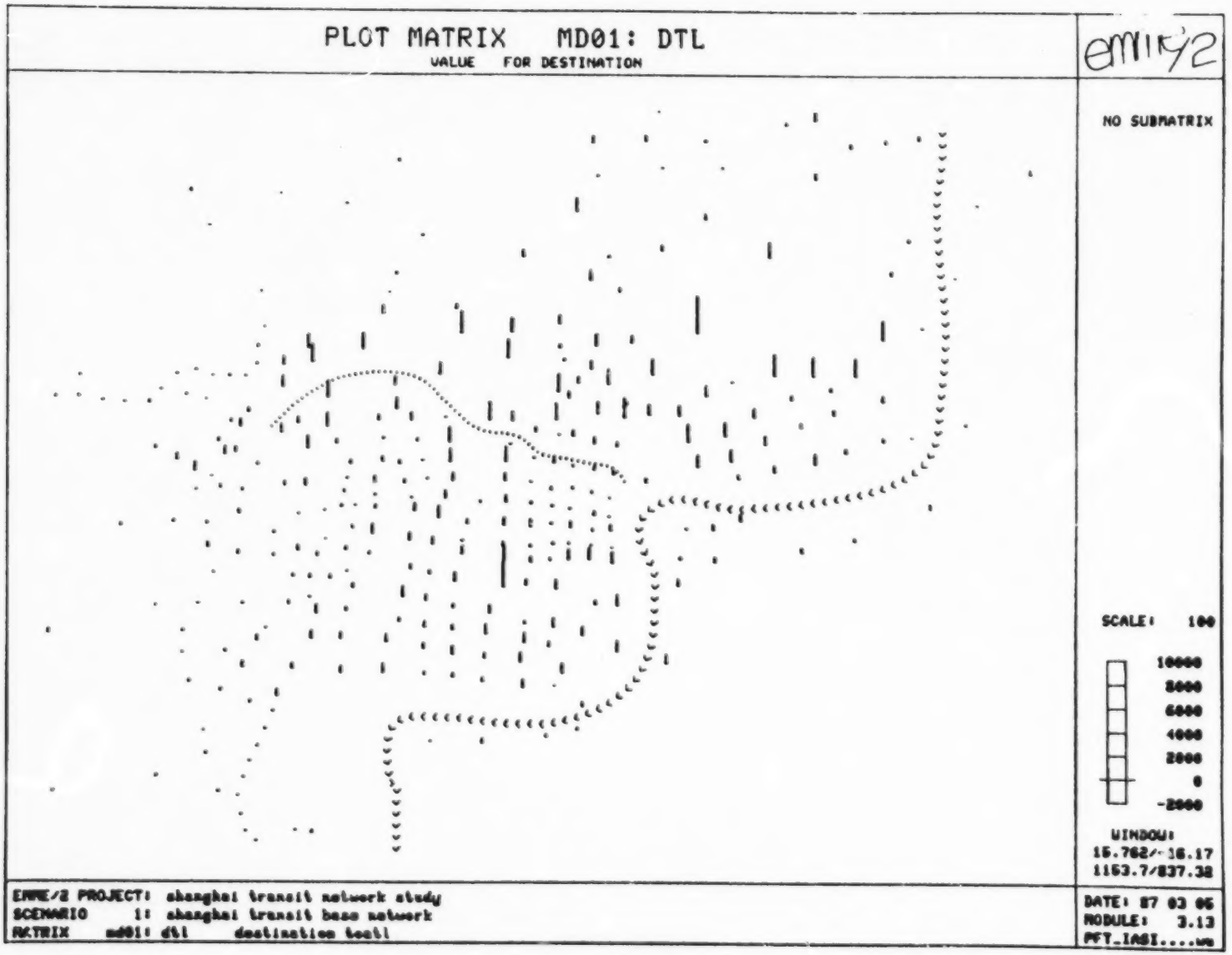

Figure 4.2 : Total D trip distribution

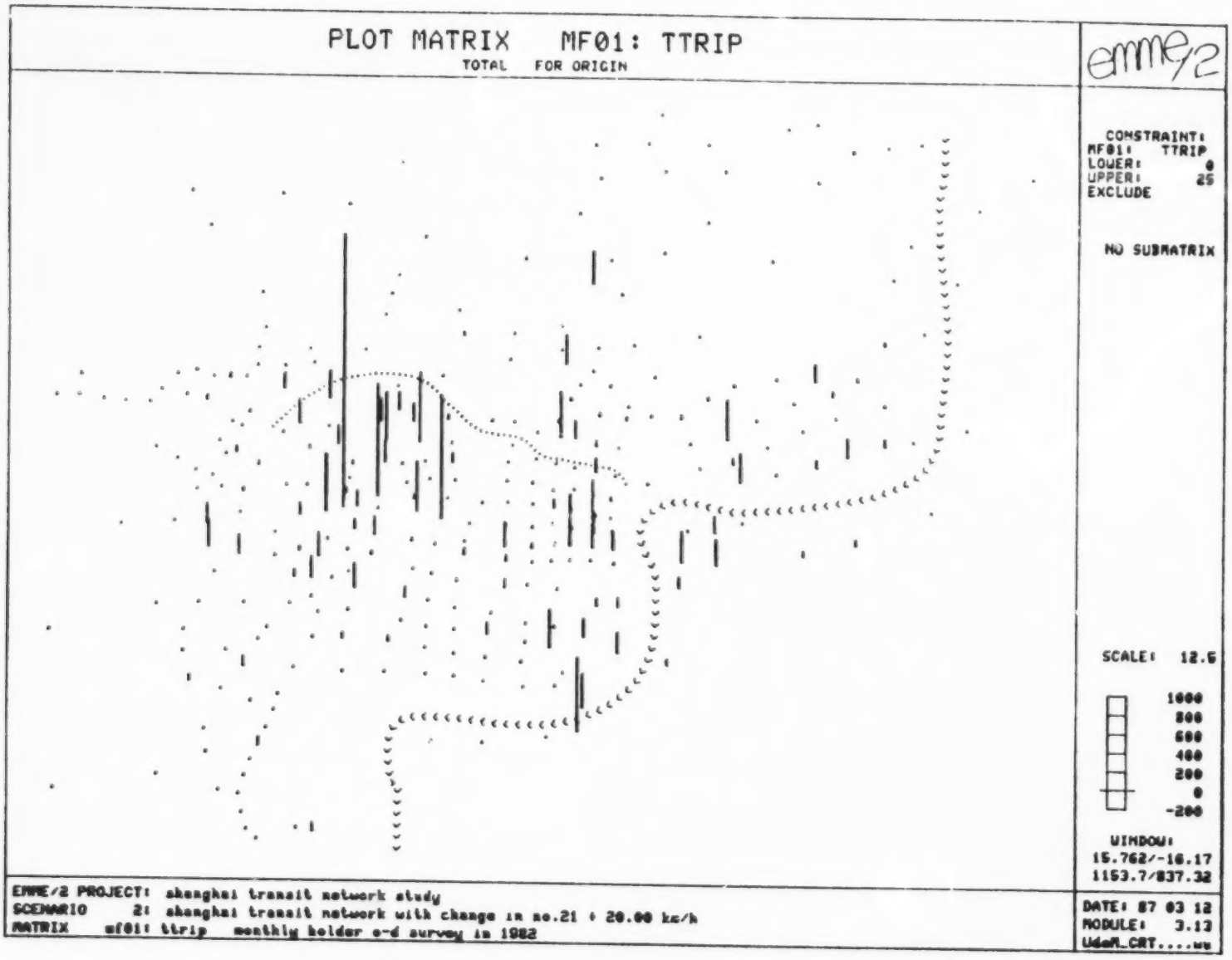

Figure 4.3 : Total O trip distribution with the constraint

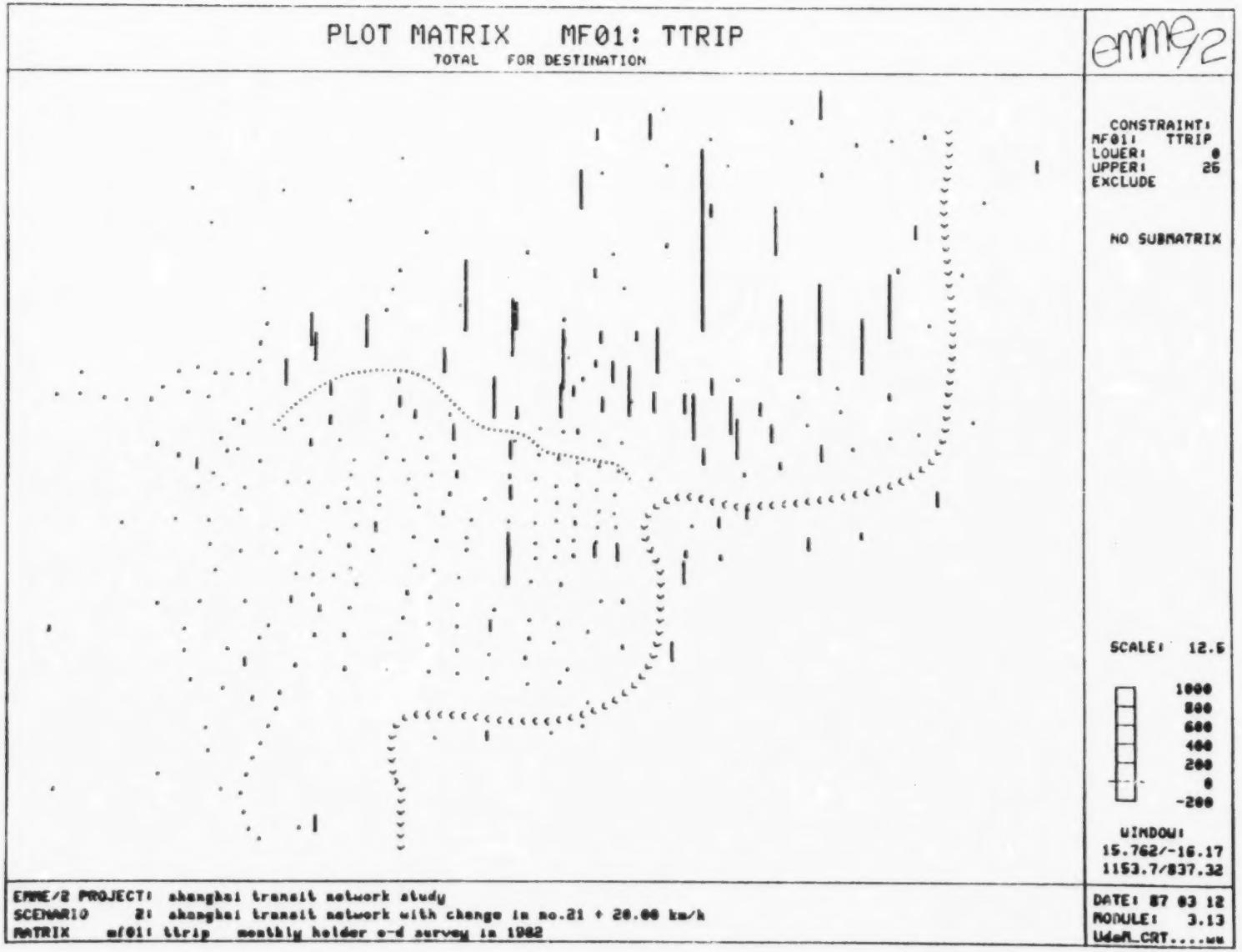

Figure 4.4 : Total D trip distribution with the constraint

Figure 4.5 shows OD pairs with trips larger than 1000 and Figure 4.6 shows OD pairs with trips larger than 500. From the two figures, a general desire flow, i.e. OD trip pattern, of those pairs is found. There is a very strong flow from GB6 where there are many large O trips, indicated in 4.1.1, to GB8 and GB9 where there are quite a lot of large D trips as explained above.

Another point is that there is also a quite heavier desire flow from GB3 to GB8 and GB9.

The analysis in 4.1.1 and 4.1.2 is carried only for some large O and D trip zones and large OD pairs which might occupy small portions of total trips. We will soon touch upon the aggregating zones.

4.1.3 General OD desire flow

The desire flows for those 16 areas are computed. Figure 4.7 shows the general desire flows from a group of zones in GB6 to the other areas in the network. Figure 4.8 shows the general desire flow from all other areas to zones in GB6. It is seen that there are considerable trips originated at GB6 to GB8 and GB9. The flow movement is somewhat directed from south-west to north-east.

Figure 4.9 shows the desire flows from a group of zones in area GB10 to all other areas. Figure 4.10 shows the desire flows from all other areas to GB10 which means that there exists strong flow movements between GB10 and GB8, GB9.

Let us take a closer look at Figure 4.11 which shows the desire flows from a group of zones in GB9 to all other areas. Figure 4.12 shows the desire flows of all areas to GB9. By comparing both figures, we find the GB9 can be viewed as an attraction area (based on the OD matrix) and flows are very directional and especially larger from GB6 to GB5, going towards the same direction as shown in Figure 4.12. In Figures 4.13 and Figure 4.14, we can see about the same flow situations for a group of zones in GB8 as displayed in Figures 4.11 and 4.12.

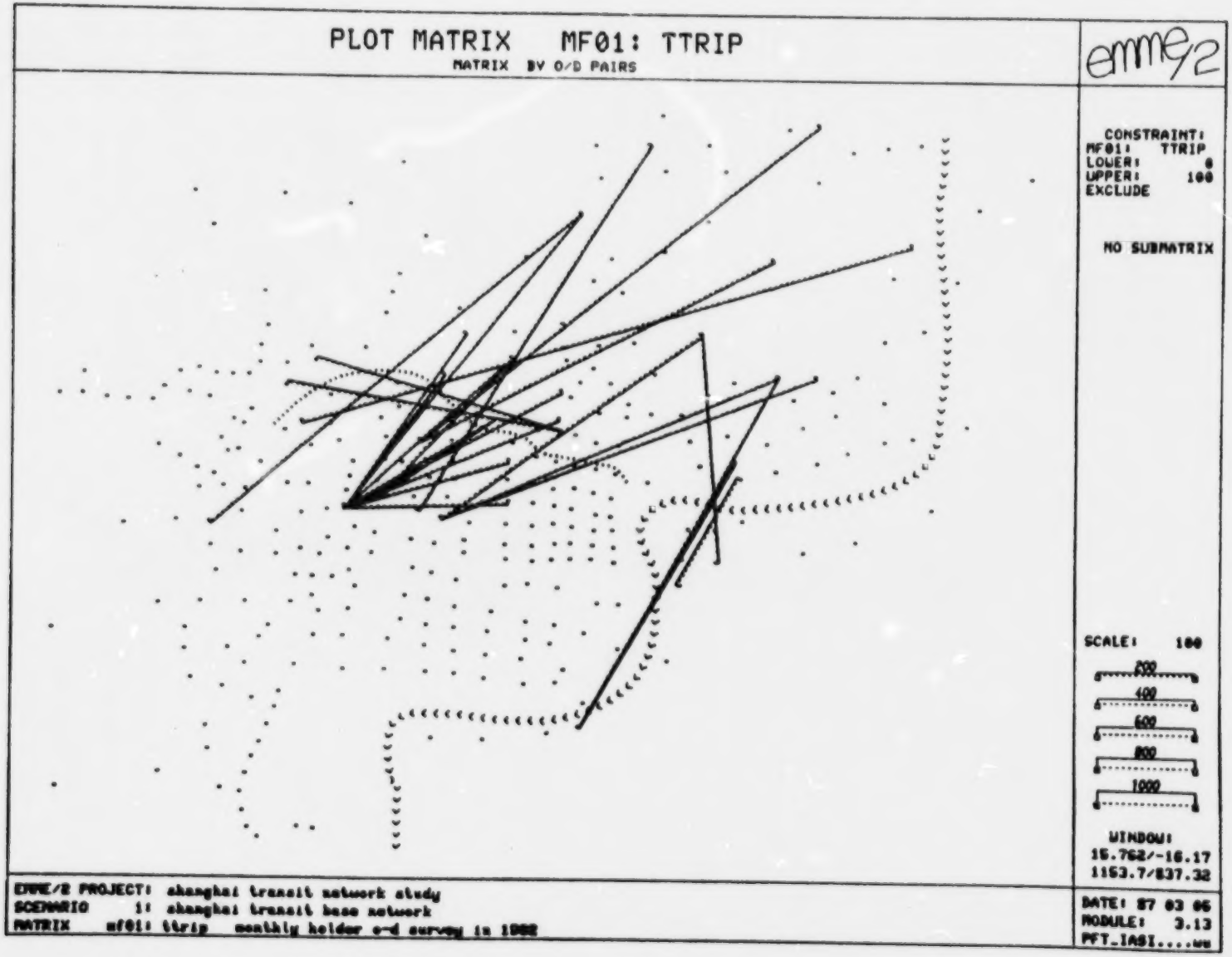

Figure 4.5 : Large OD pairs with the constraint

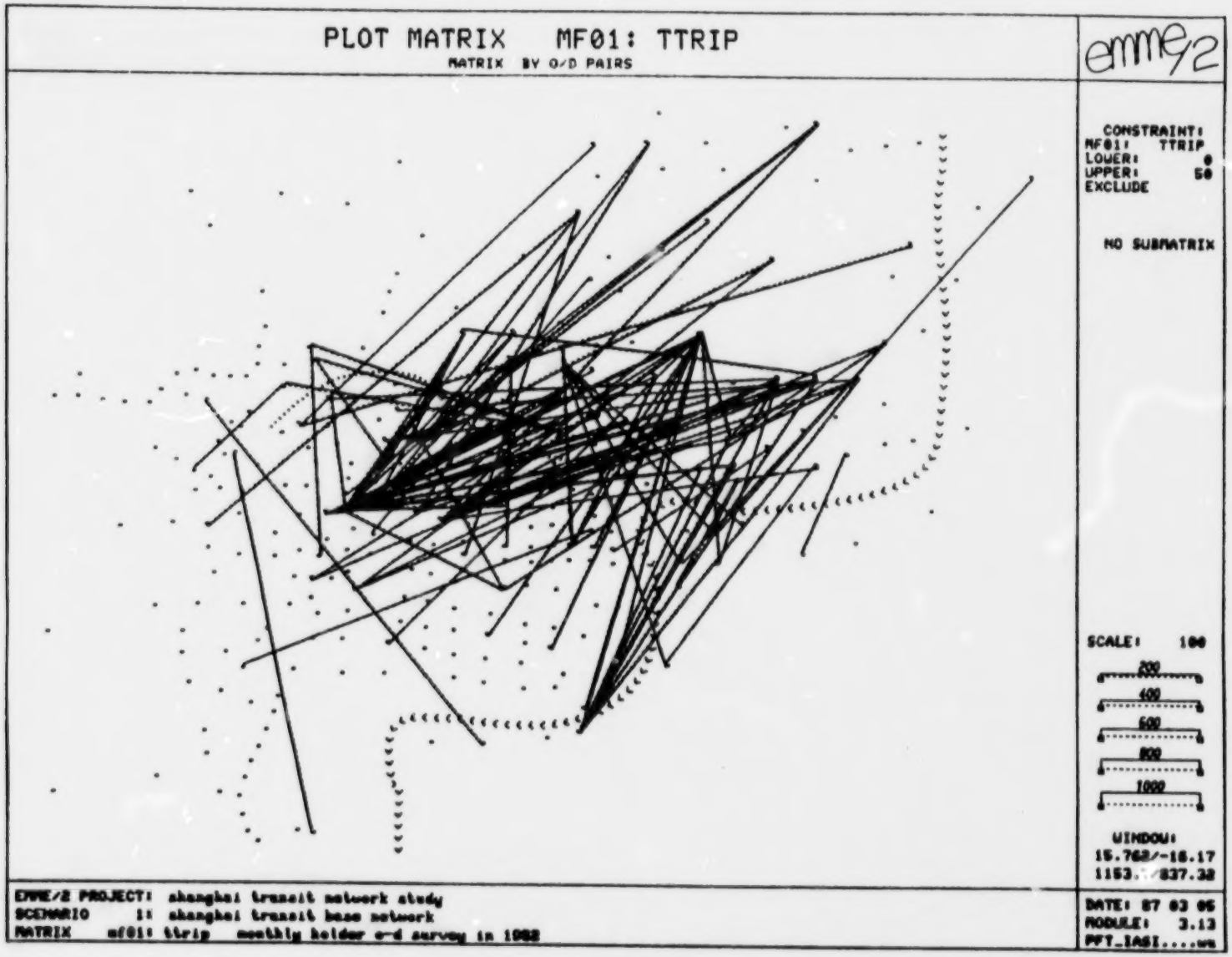

Figure 4.6 : Large OD pairs with the constraint

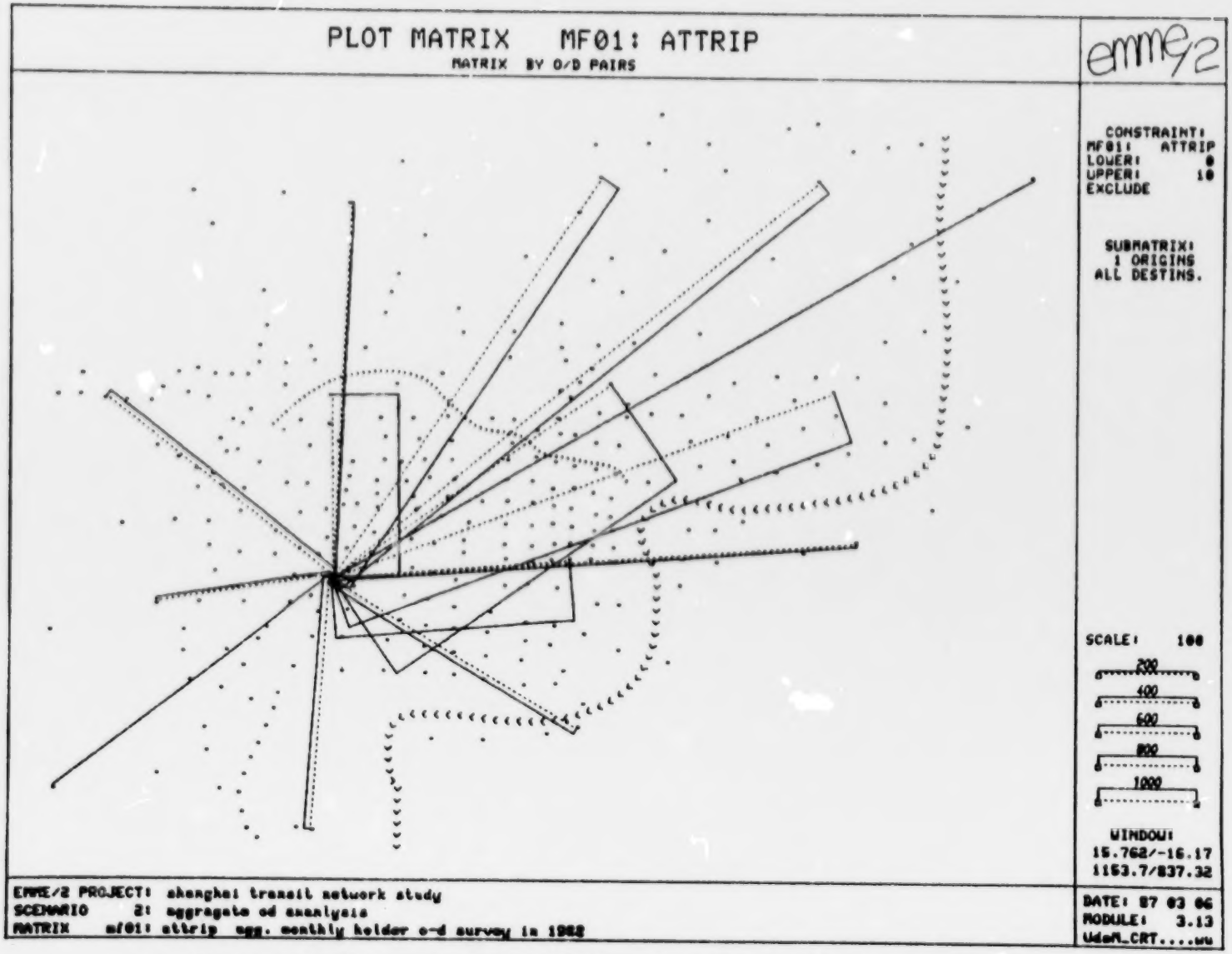

Figure 4.7 : The general desire flows from GB6 to all other areas

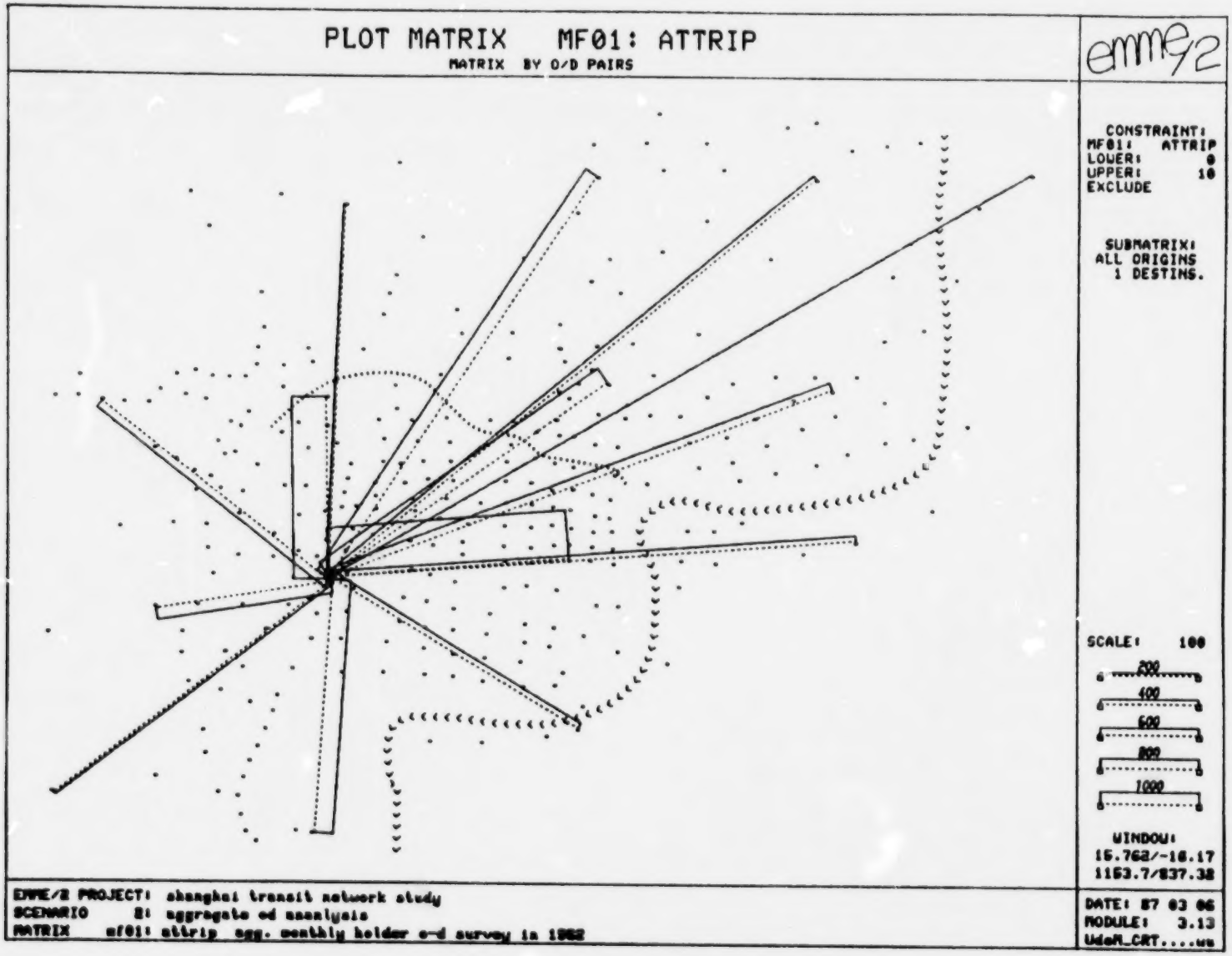

Figure 4.8 : The general desire flows from all the other areas to GB6

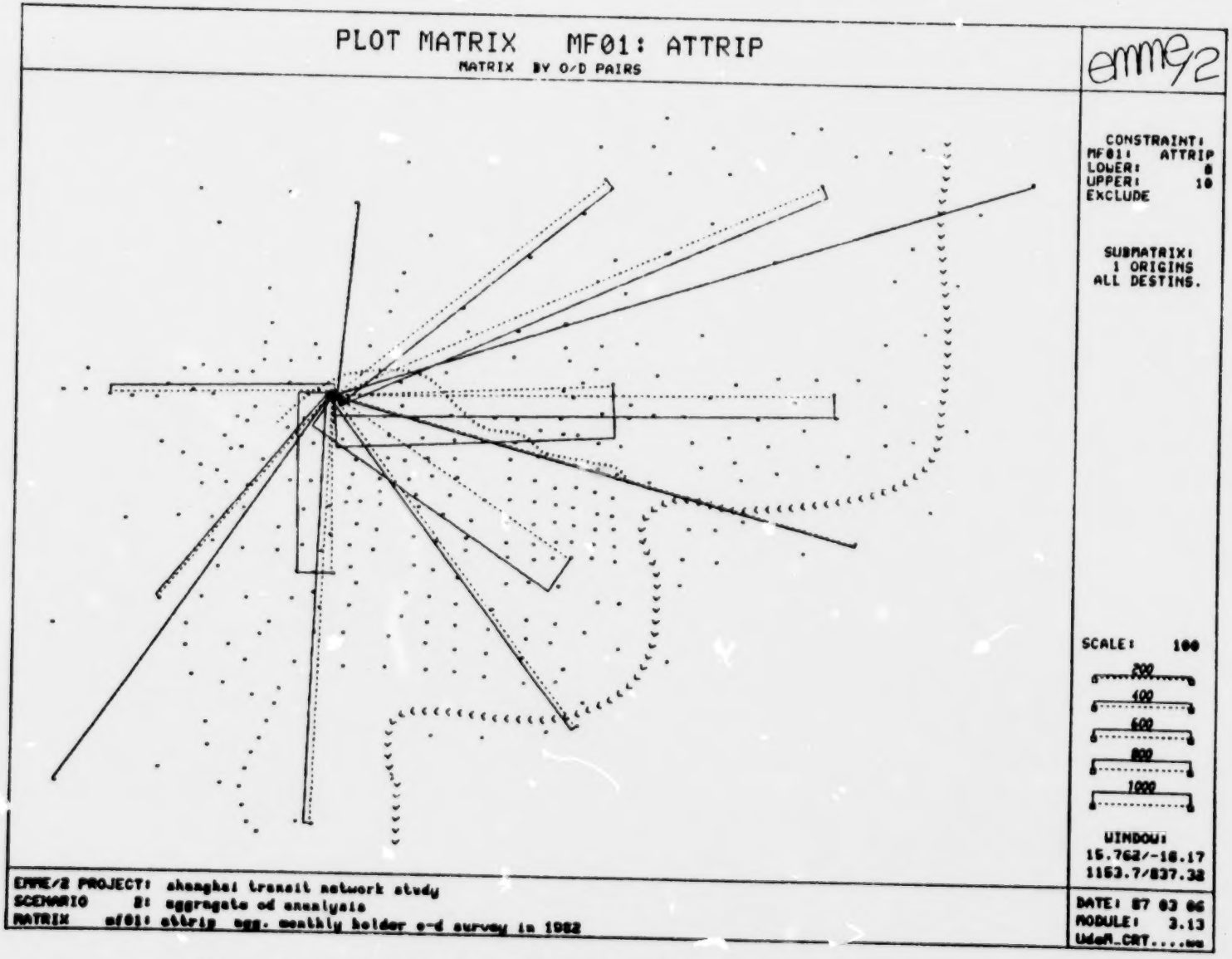

Figure 4.9 : The general desire flows from GB10 to all other areas

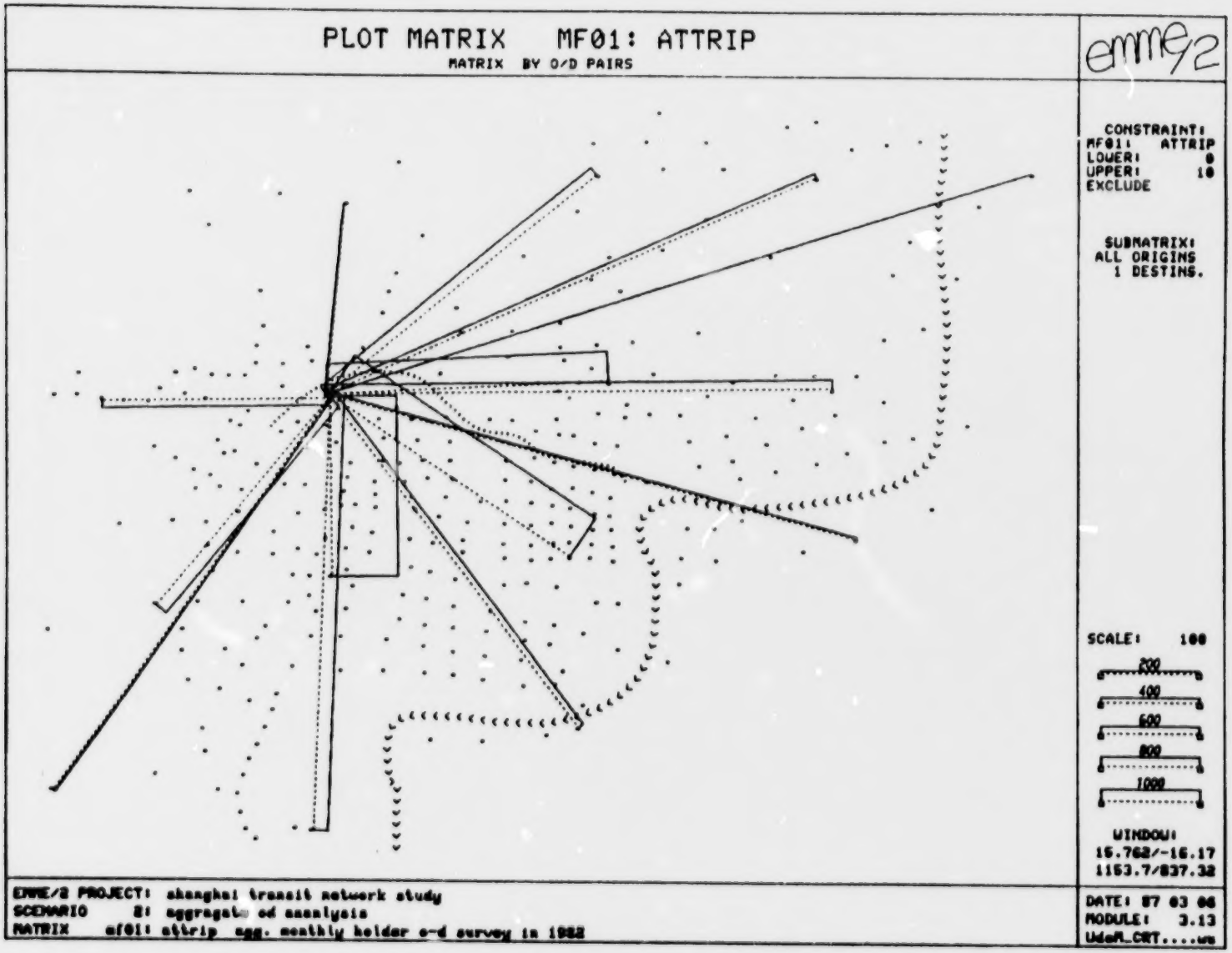

Figure 4.10 : The general desire flows from all the other areas to GB10

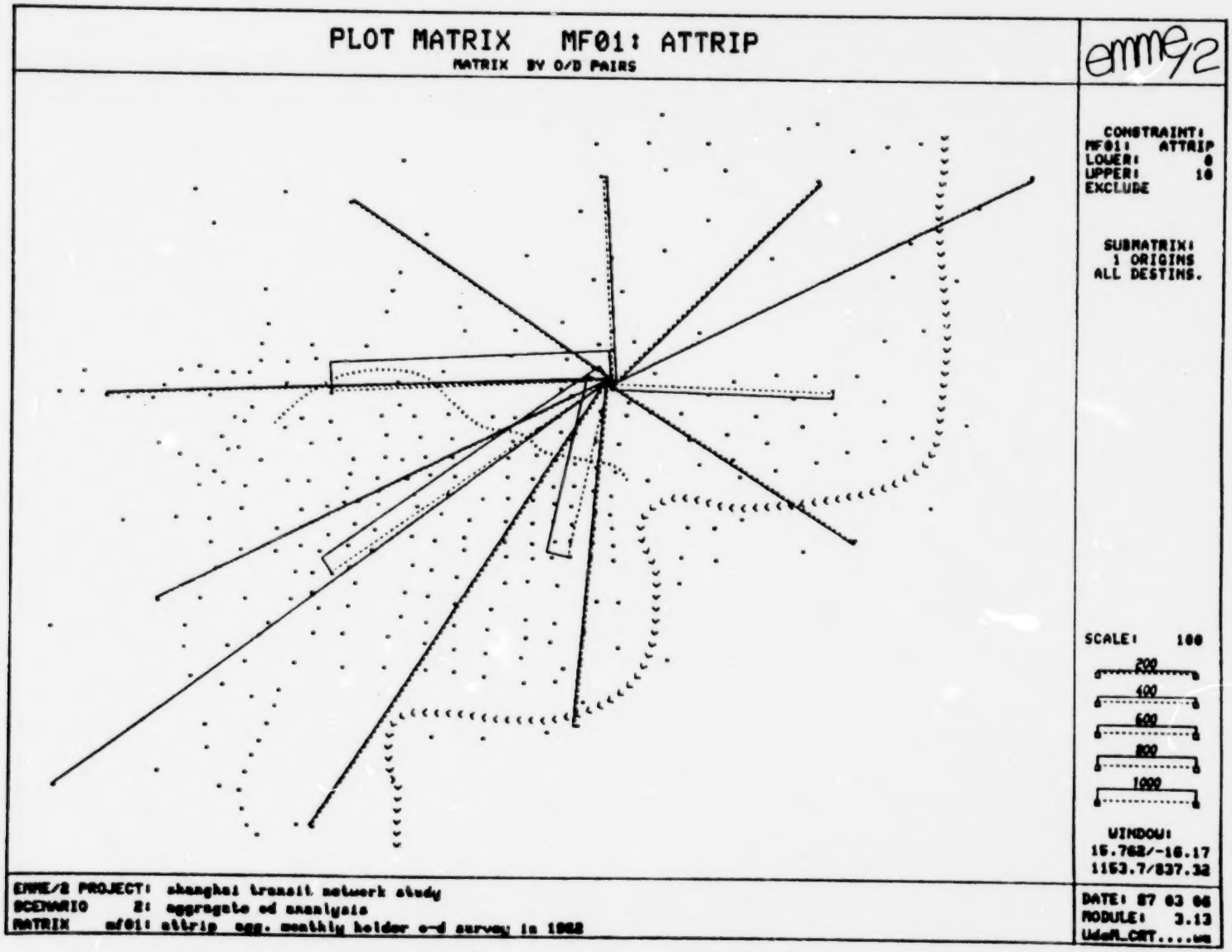

Figure 4.11 : The general desire flows from GB9 to all the other areas

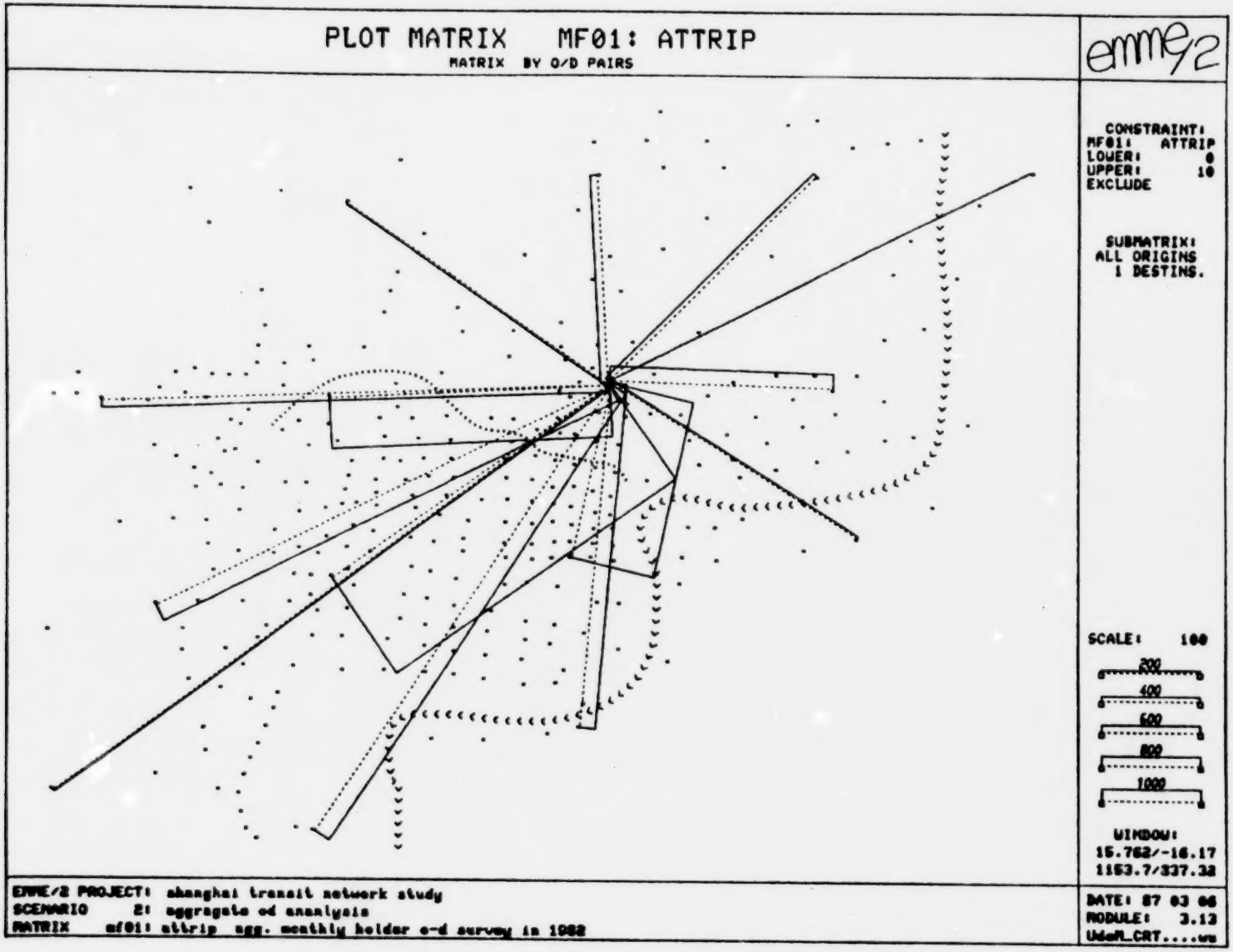

Figure 4.12 : The general desire flows from all the other areas to GB9

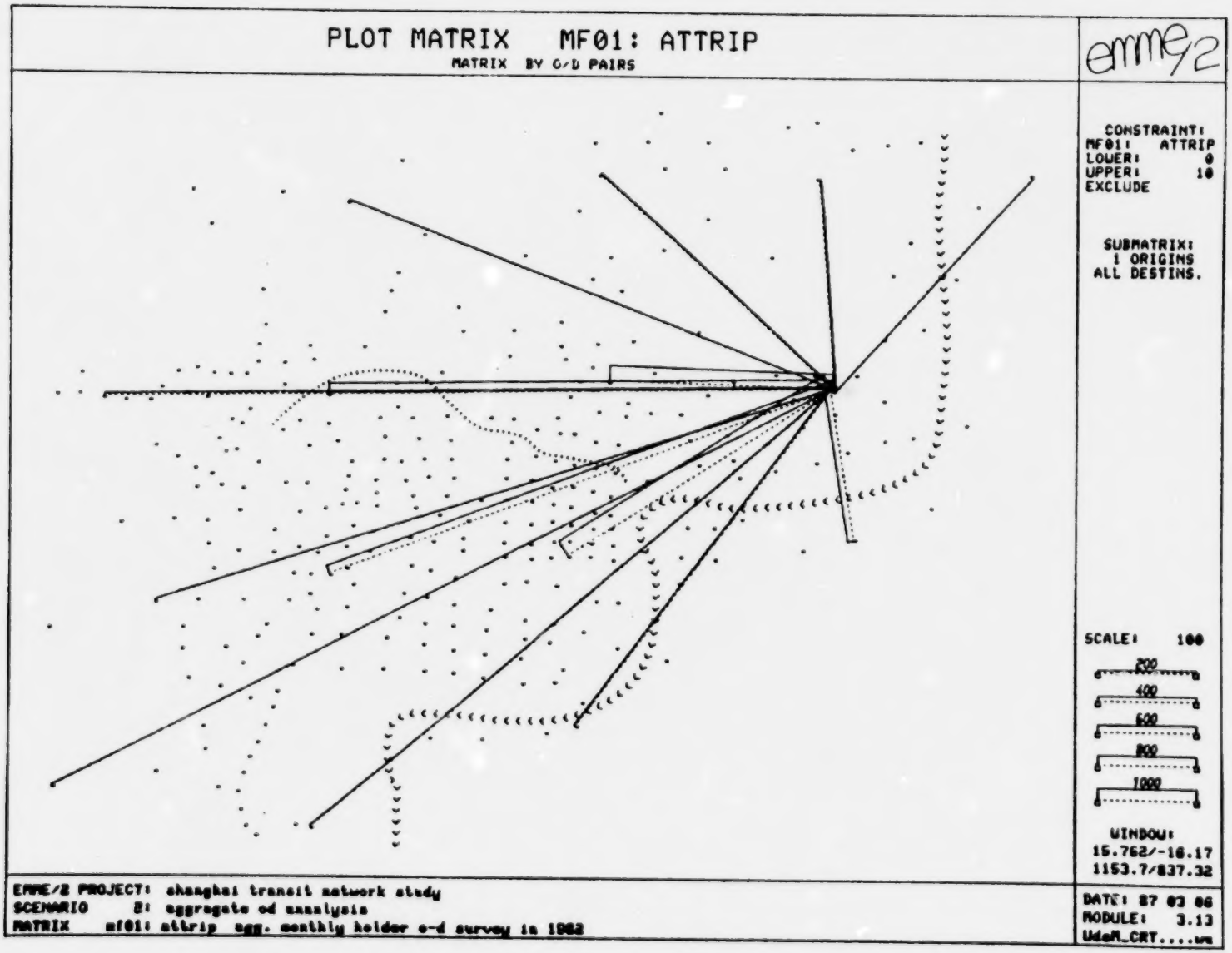

Figure 4.13 : The general desire flows from GB8 to all other areas

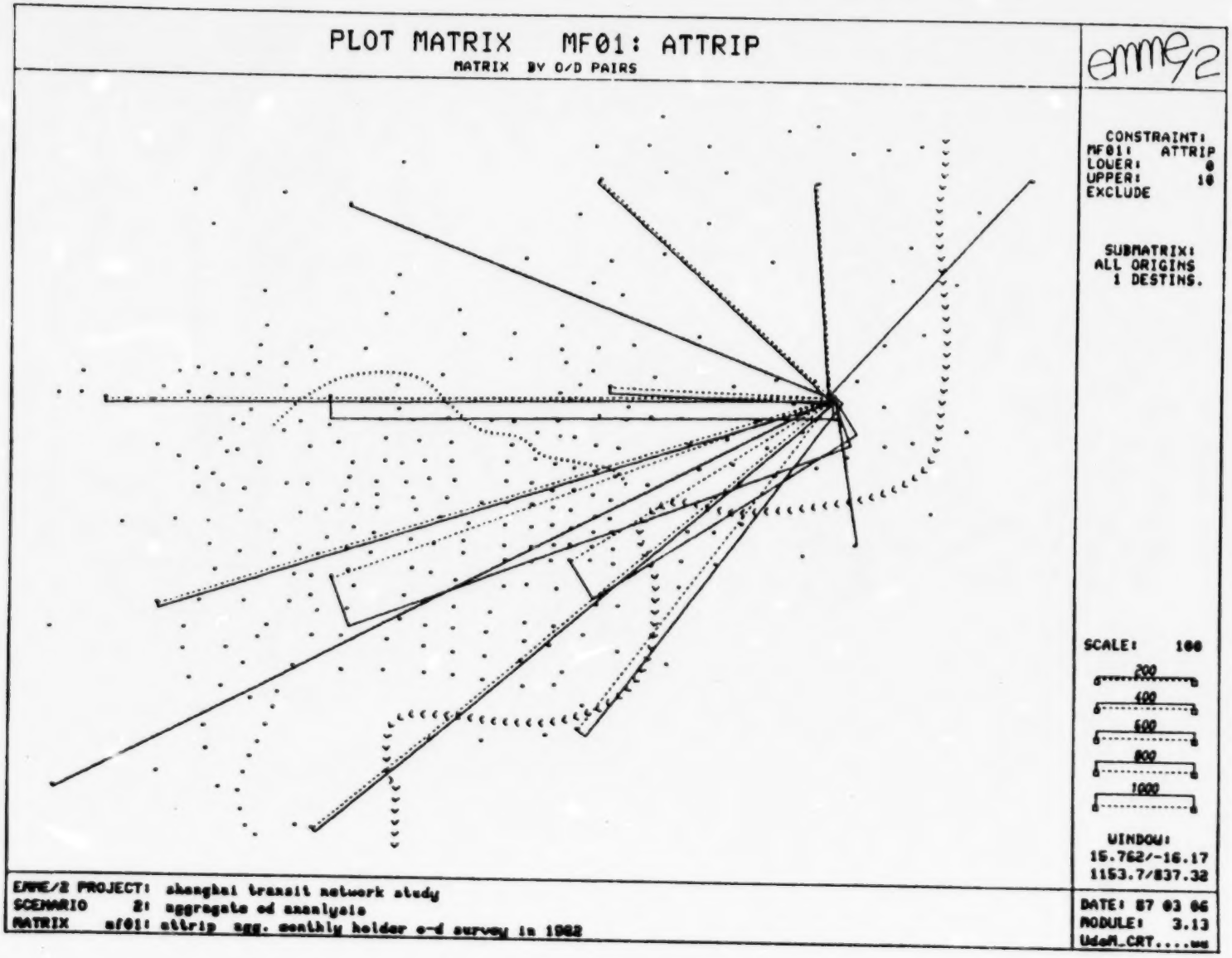

Figure 4.14 : The general desire flows from all the other areas to the GB8

Figures 4.15 and 4.16 present a desire flow pattern situation for the downtown area GB5. In fact, in this area, there is a considerable amount of trips generated to other areas, especially to the areas such as GB9 and GB8 while, on the other hand, the area also attracts a lot of trips from GB10 and GB6.

4.1.4 Conclusions

From the above representation of the current OD trip pattern, we can say that:

1) the large total O trip areas are more clustered while the large total D trip areas are more diversified;

2) the OD trip pattern in general is very directional, that is, the flow is directed towards GB5, GB6 and GB9, and GB8. There are, of course, some other exceptional cases which can not be considered otherwise.

This typical OD trip pattern is gradually evaluated according to the economic and social growth in Shanghai. GB5 and GB6 were and are regarded as the population-intensive residential areas, while GB9 and GB8 are considered as somewhat intensive-industrial areas where there are a lot of larger factories.

3) based on the analysis from the data available, the scheme of the subway being considered is not suitable for the transit demand.

4.2 Transit supply

In this section, we are going to discuss the basic structure of the transit network in Shanghai. Figure 3.3 depicts the basic lines in the network.

4.2.1 Turn-around lines

There are some bus lines travelling in a turn-around fashion. This kind of bus line features a route going in a way deviated from the shortest path between two terminals of their own. Figures 4.17, 4.18 and 4.19

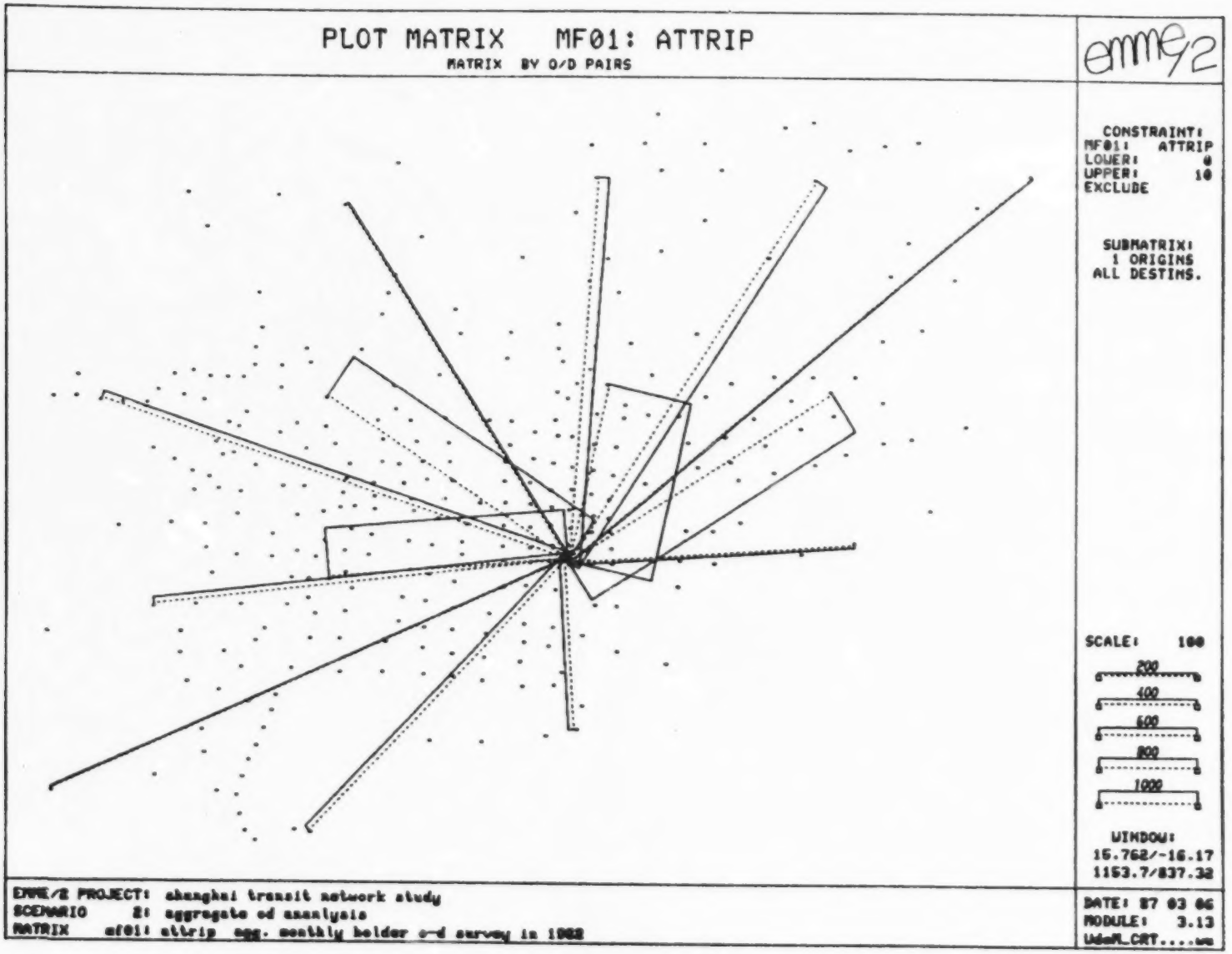

Figure 4.15 : The general desire flows from GB5 to all other areas

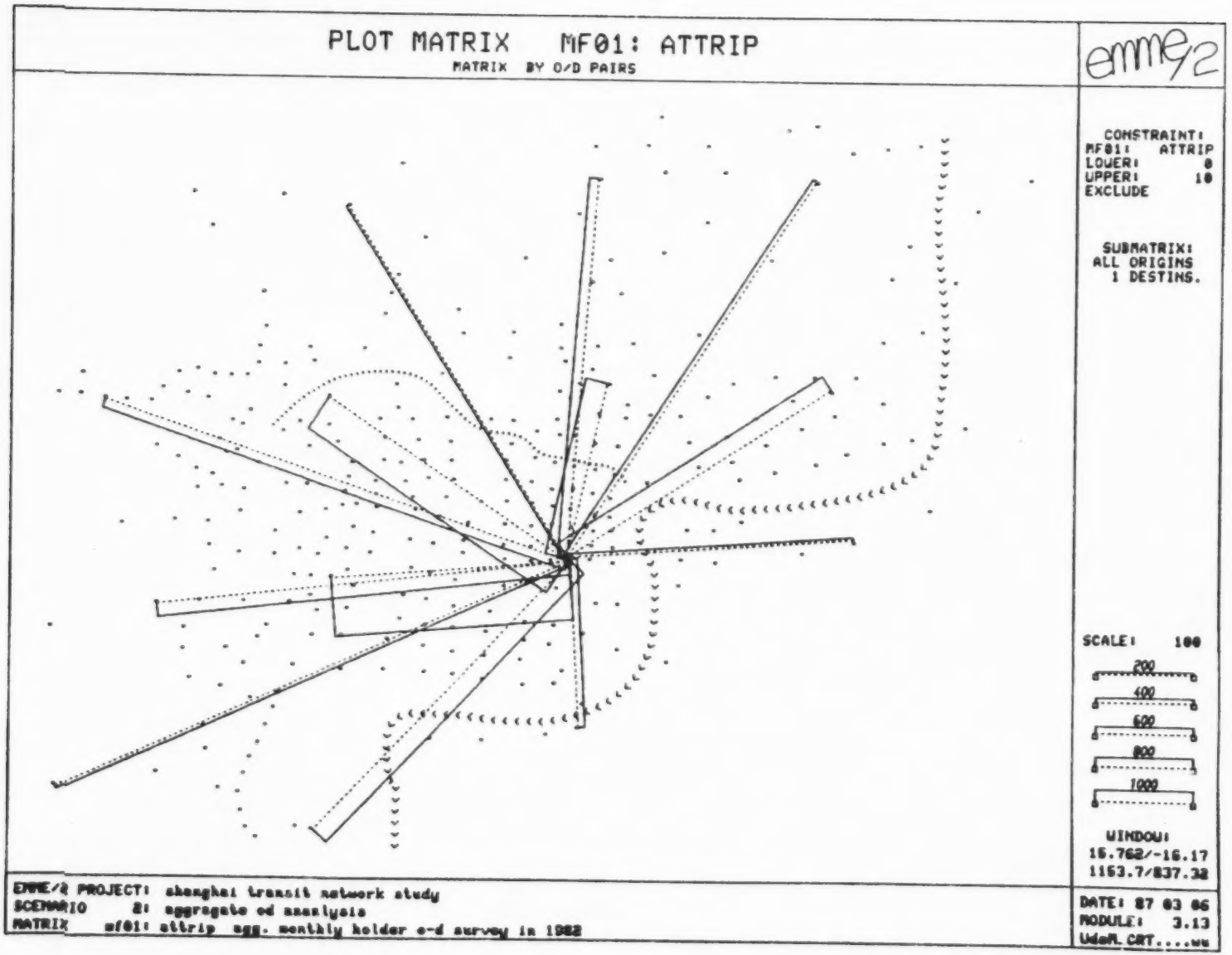

Figure 4.16 : The general desire flows from all the other areas to GB5

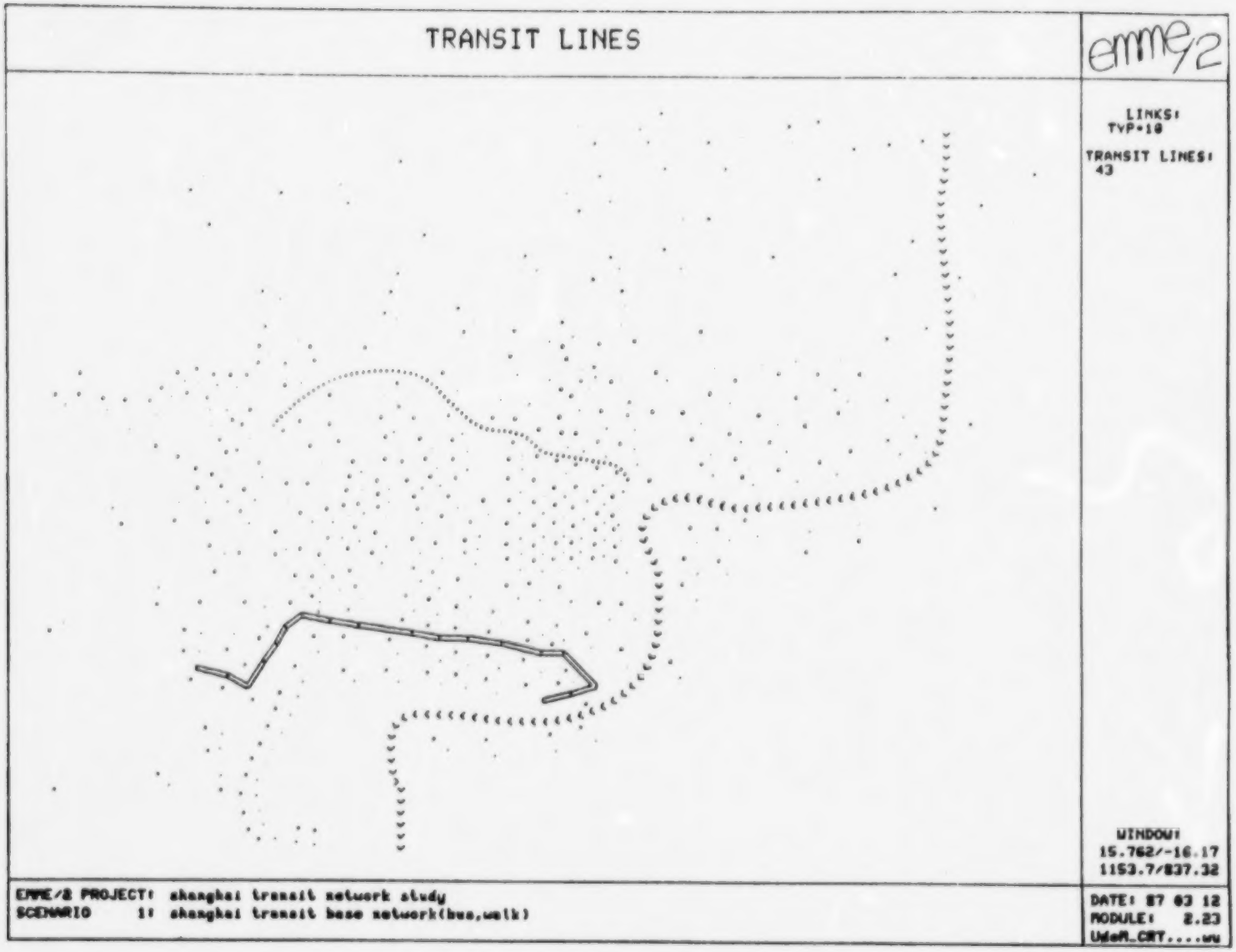

Figure 4.17 : Transit line 43

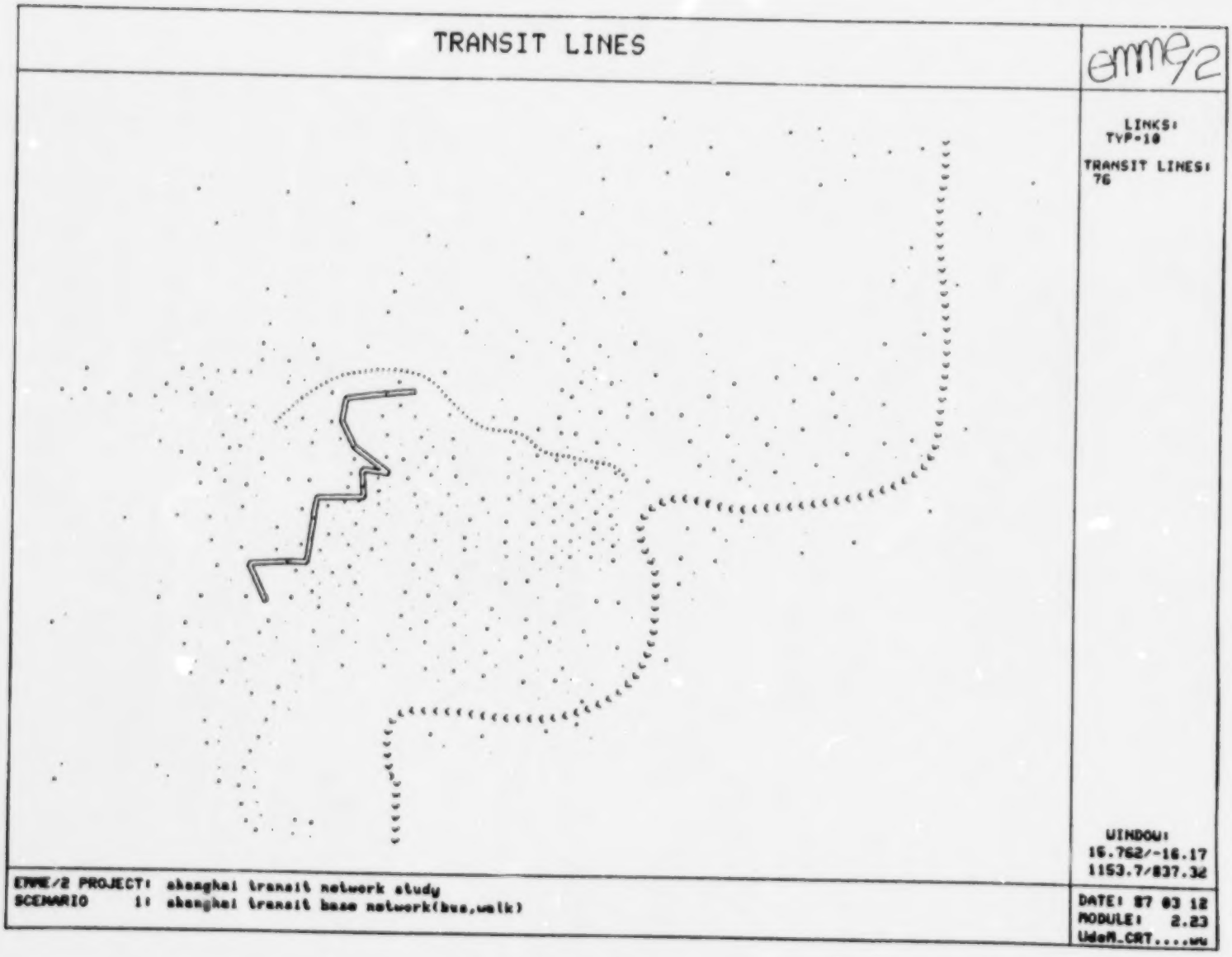

Figure 4.18 : Transit line 76

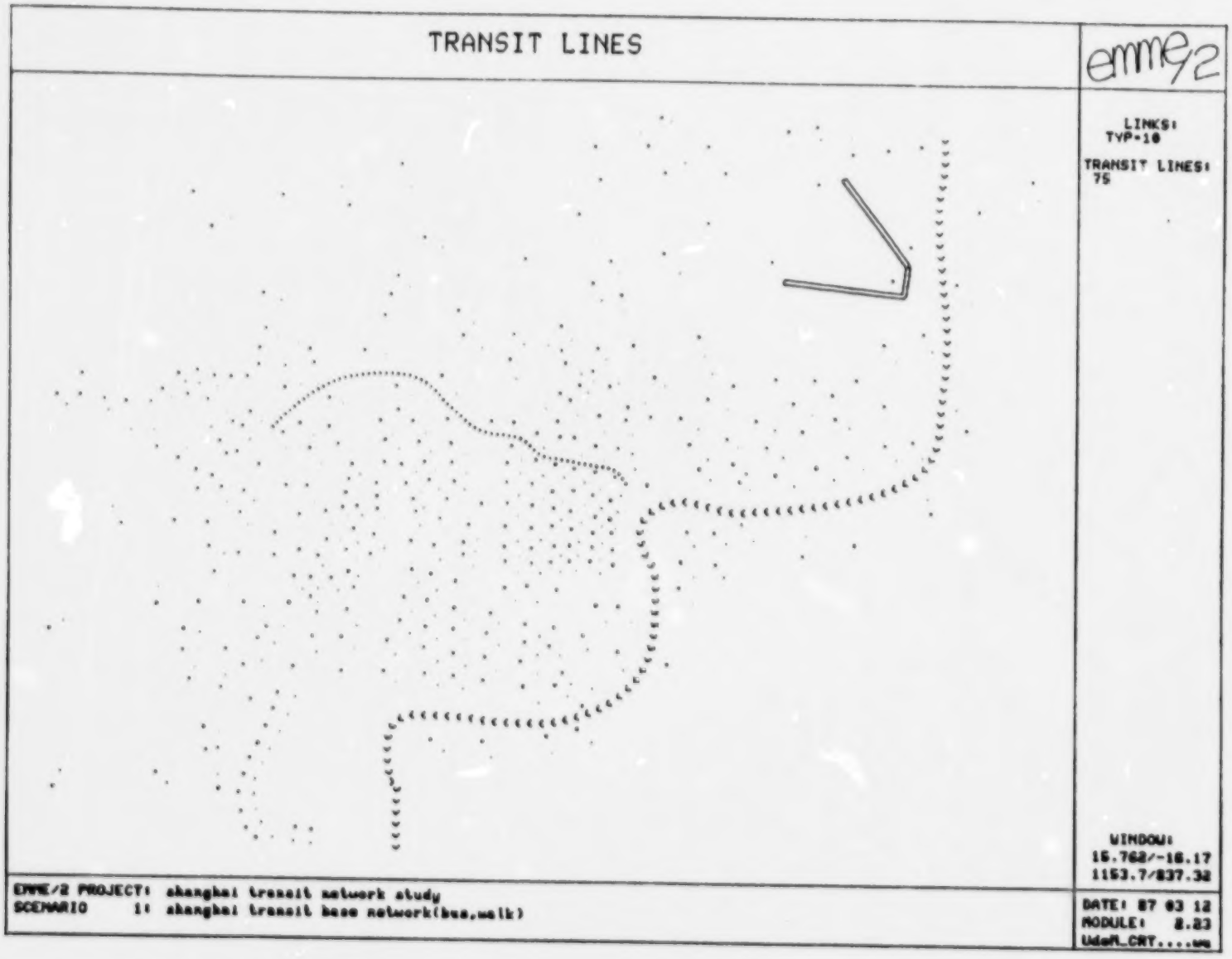

Figure 4.19 : Transit line 75

illustrate the typical bus lines 43, 76 and 75. It is accepted to have bus lines as straight as possible as long as some unecessary travel time incurred by passengers using these lines is reduced to a minimum.

4.2.2 More bus lines passing and bus terminals at GB5

There are considerable bus lines passing Bund in GB5 and many bus stops are located in the area. Because of this, the area becomes a very attractive and easily accessible transit. As you can see, this is a historical event.

4.2.3 A mixed line pattern network

The transit (line) network of Shanghai could not be generalized as being a typical transit network such as grid-type or radiate-type. It is really a mixed transit network that includes a variety of bus lines in all kinds of directions and patterns. However, more transit service is provided downtown than on the outskirts.

4.3 EMME/2 system calibration

A calibration of the EMME/2 system is a system that is adjusted by having proper parameters placed in it in such a way that the output of the system can be matched with the data from the survey. A good calibration makes the model more reliable, usable and acceptable. In our case, the EMME/2 system calibration is carried out so that the results from the system are comparable with the survey conducted in 1982. Due to the data available from the survey, only the issuers of average in-vehicle time and average number of transfers and travel pattern (i.e. OD travel path) are considered. After ten iterations of the calibrations, the simulated results are shown in Table 4.1 and the survey results indicating some important parameters such as walk, wait and bord weight are shown in Table 4.2.

Table 4.1 : A comparison between the survey and simulated results (min.)

	Survey results	Simulated results
Average number of transfers	1,19	1,16
Total transit time		51,42
In-vehicle time	36,20	38,66
Walk time		6,70
Wait time		2,59
Board time		3,47

Table 4.2 : Some important parameters in EMME/2 for Shanghai

board time	wait factor	wait weight	walk weight	transfer weight
3 (min.)	0,5	4,5	10	5,3

Since the reality is much more complicated than the computer simulation, there is no end to a perfect calibration. Therefore the results thus far are considered to be acceptable for having a good model in the system which will be used for the successful comprehensive analysis.

From the properties of the OD matrix mentioned earlier, we understand that the average transit time 51,42 min. is expected since it is larger than any other trip-purpose transit time.

4.4 Travel pattern influenced by the demand and the supply

In this section, we will take a closer look at the simulated (which is reasonable in reality) travel pattern influenced by both the demand and the supply.

4.4.1 Travel path

Figure 4.20-A shows us passenger flow on the network. There are considerably heavy flows passing through downtown and Bund in area GB5. This could be due to many factors. Because of the good transit service in

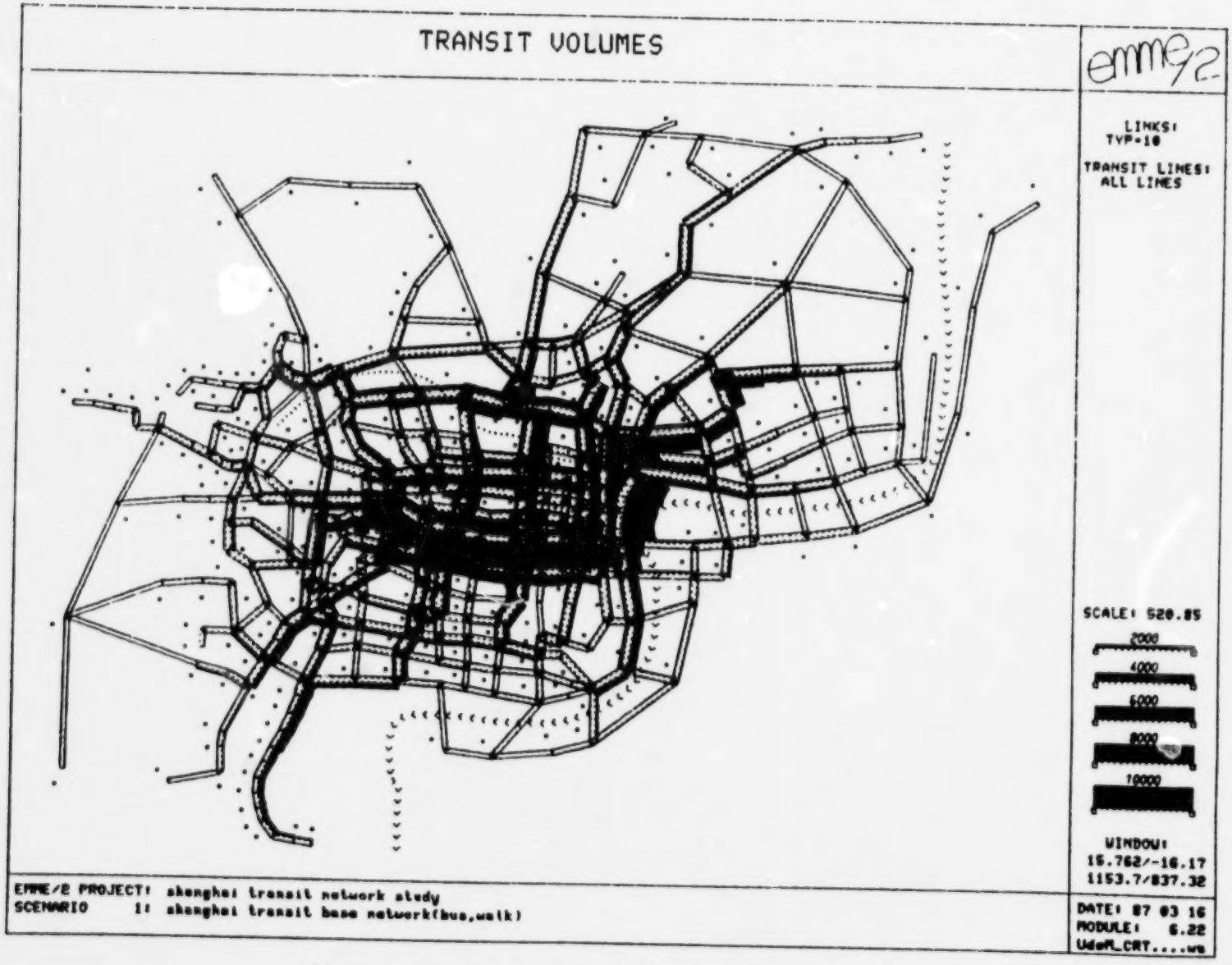

Figure 4.20a : Passenger flows in the current transit network

this area, many trips are attracted into that area, resulting in the congestion of the area. Do all the passengers have to pass through that area? Can some measures be taken to alleviate the situation? Before we answer these questions, let us take a look at the travel path between zones 65, 50, 77 and 316 and all the zones in GB9 as shown in Figure 4.20-B.

In this figure it can be seen that these trips are forced by the current network to travel through the downtown area (in GB5) and take transfers at Bund and then go north in a nondirect way. If a new bus line is established to attract some of these passenger flows so as not to pass through the downtown area, then the congestion in the area would probably be reduced and the travel time may be decreased. We will discuss in detail in Section 5.

In Figure 4.21 the passenger flows between GB6, GB8, and GB9 certainly proved the above analysis.

4.4.2 Transfer node distribution

Figure 4.22 shows the distribution of the transfer nodes in the transit network. Because of the transit line structure and the OD travel pattern explained earlier, many transfer nodes occur in GB6, GB10 and Bund in GB5 where significant transfers are present.

Figure 4.23 shows the initial boardings for zones 62, 50, 77 and 316 in GB6. Figure 4.24 shows the nodes in GB5 where the amount of trips originated at these zones take transfers to the GB9. Therefore, this situation again supports our view of the travel pattern in the network.

4.4.3 "Vicious circle"

The downtown area GB6 and GB5 are the old residential areas in Shanghai. The transit system was developed mainly for transportation purposes for those areas. Due to the economic development in areas such as GB9 and GB8, the transit system was adapted to the changes in demand based

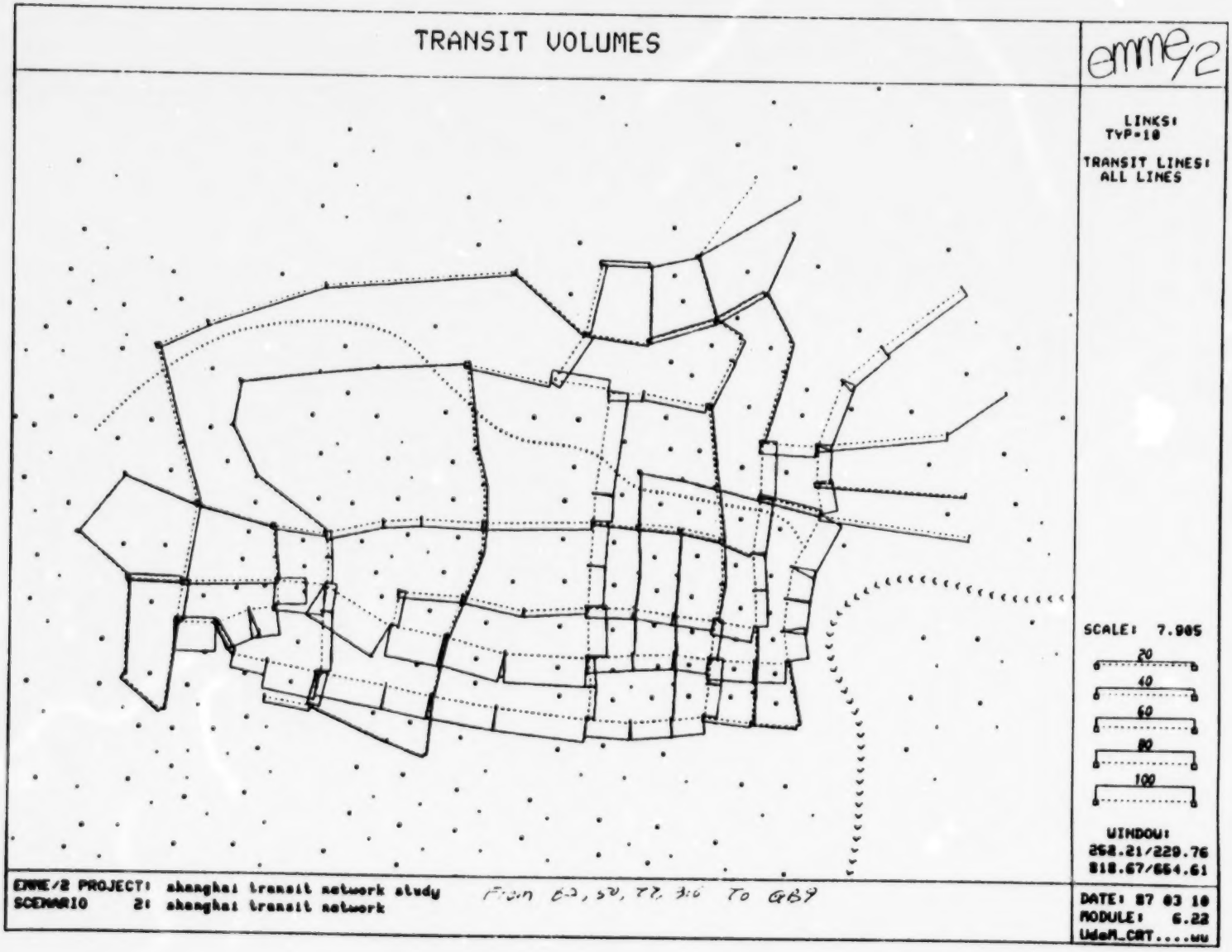

Figure 4.20b : The travel path between zones 65, 50, 77 and 316 and all the zones in GB9

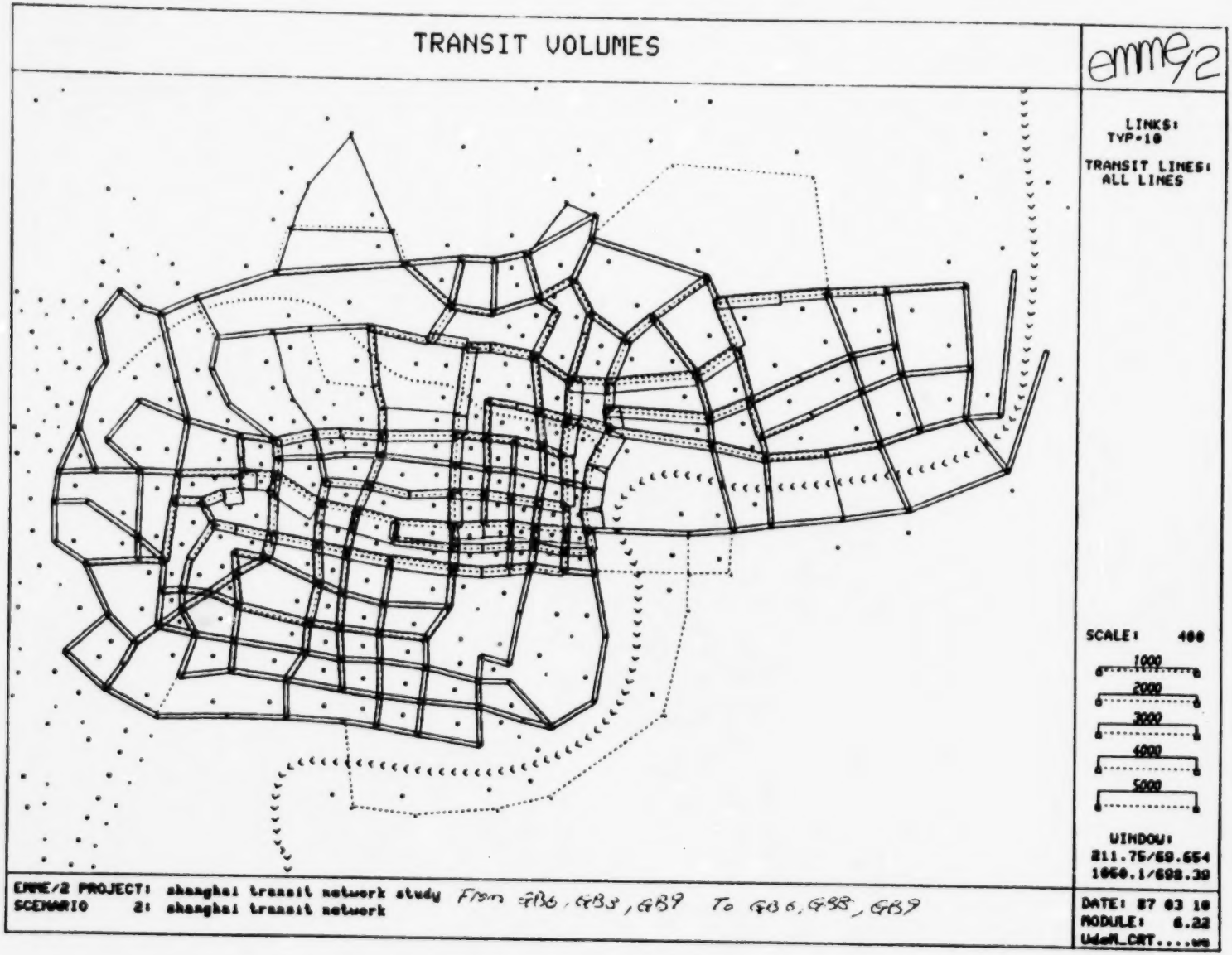

Figure 4.21 : The passenger flows between GB6, GB8 and GB9

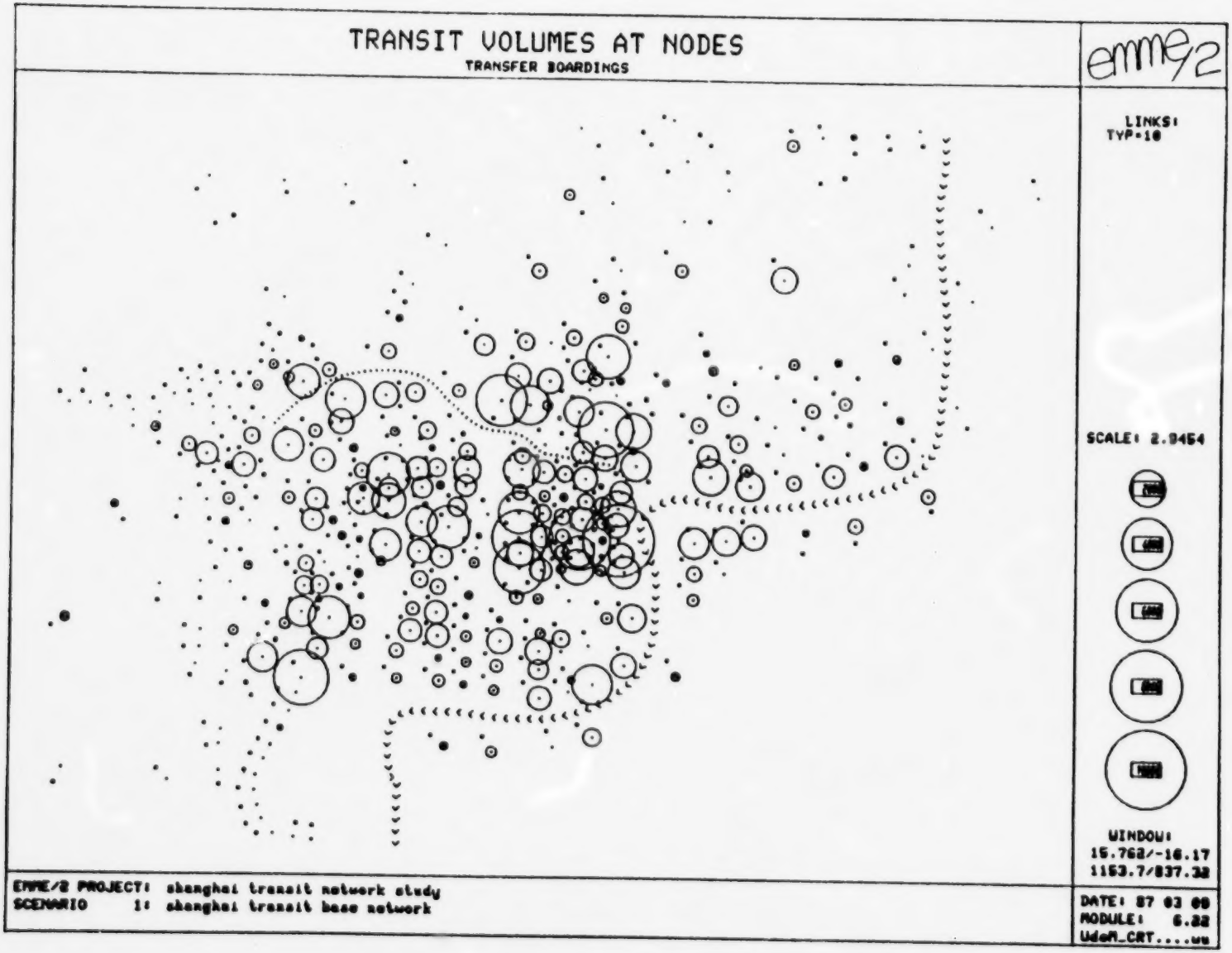

Figure 4.22 : The distribution of the transfer nodes

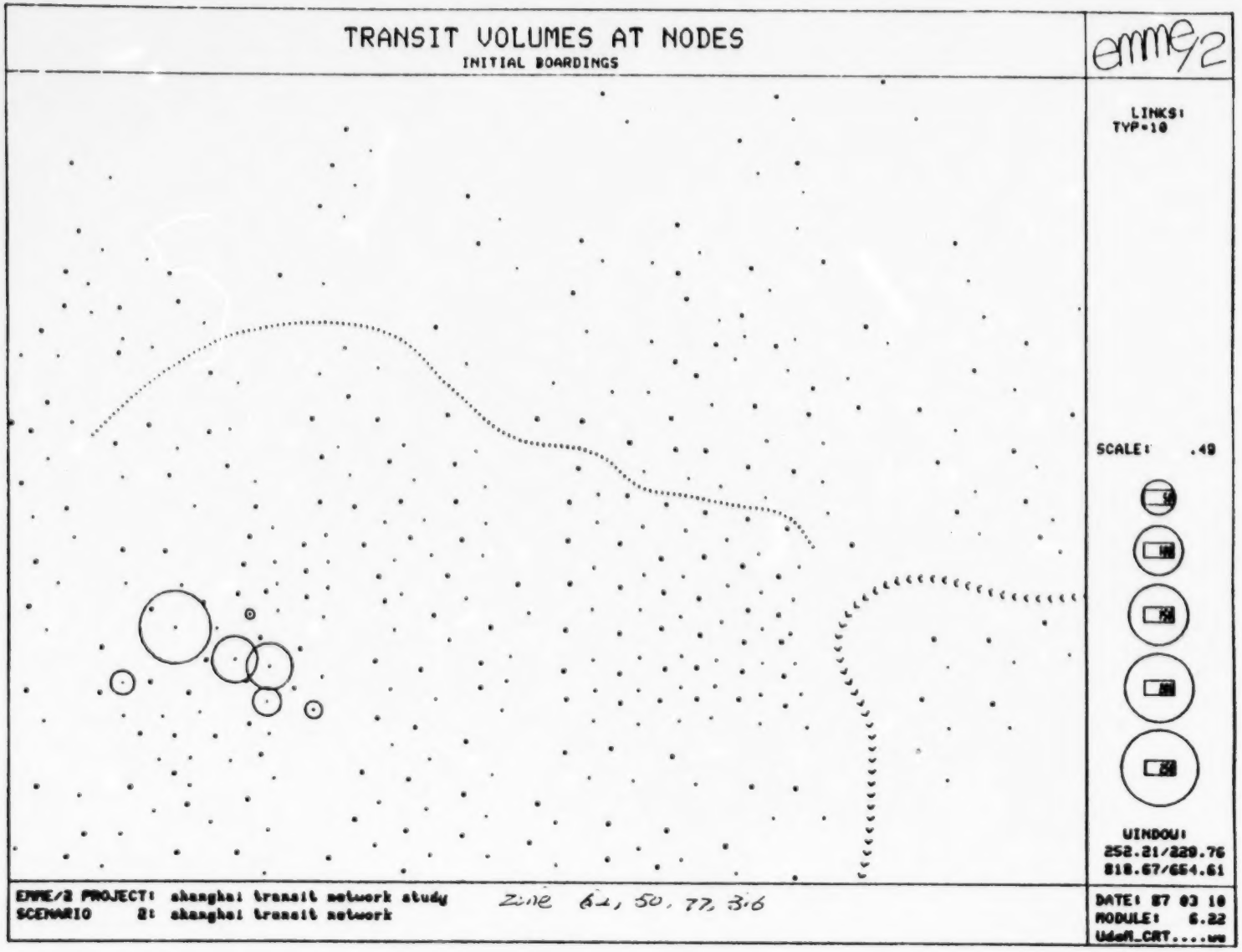

Figure 4.23 : The initial boardings for zones 62, 50, 77 and 316 in GB6

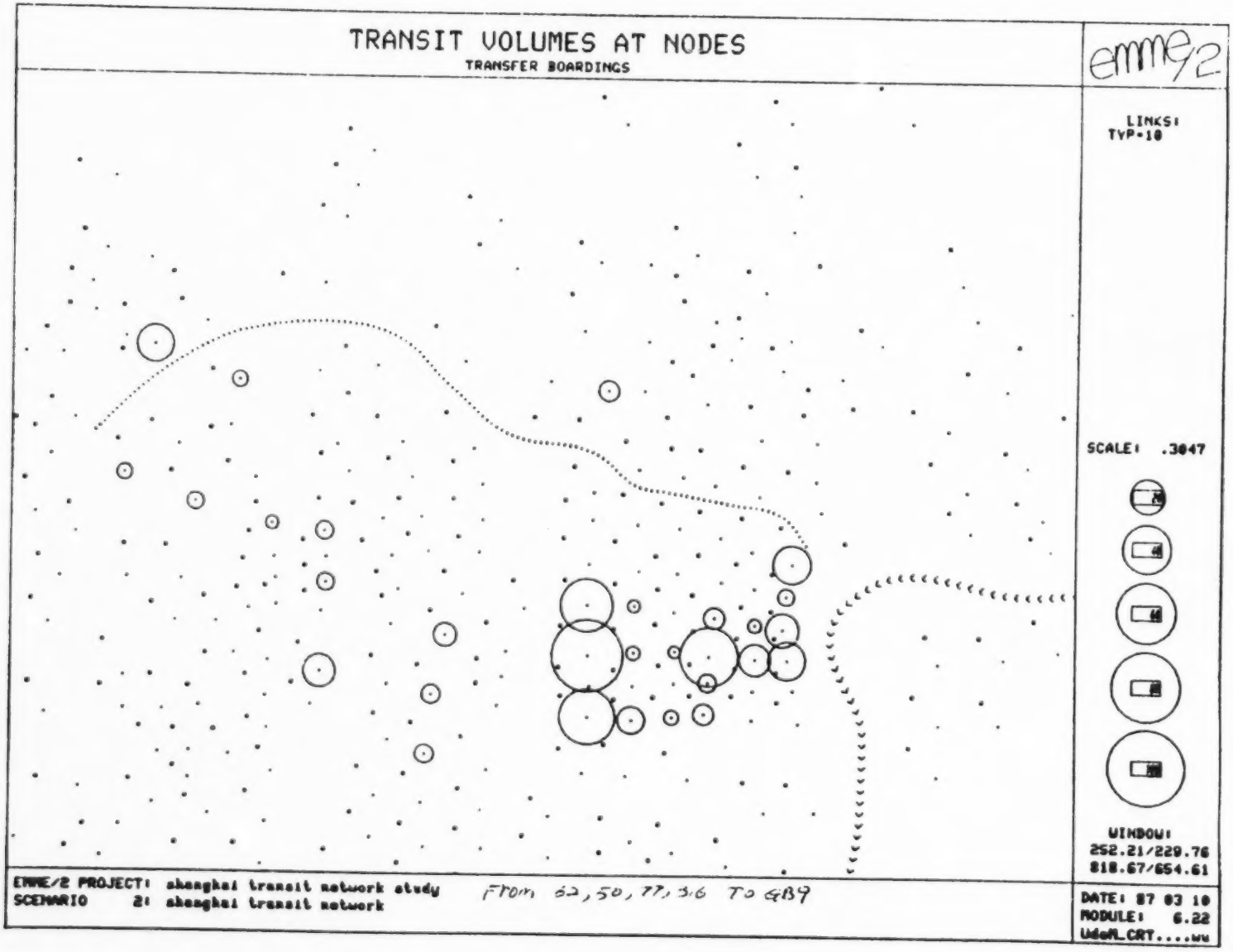

Figure 4.24 : The nodes in GB5 where the amount of trips originated at those zones take transfers to the GB9

on the old transit system. Consequently, there were a lot of trips generated to GB9 and GB8 carried by the transit system through the downtown and Bound areas in GB5, resulting in a more congested situation in these areas. Some measures were taken to put more buses and bus lines in those areas to satisfy the ever-increasing transit demand, which once again induces even more passengers from other areas than the capacity available. This is a kind of worse feedback called the "vicious circle", as shown in Figure 4.25, controlled by a conventional transit planning method. It is likely that an adaptation of more transit services for those congested corridors can make conditions even worse, i.e. it can become more congested if a comprehensive analysis is not conducted properly. The new bus line 204 recently established which passes through the Bund area is such an example.

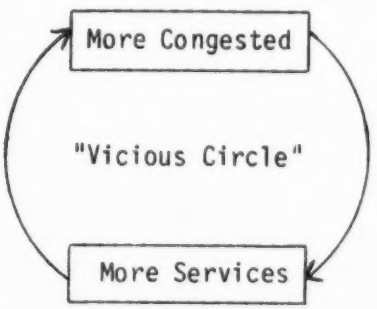

Figure 4.25 : A "vicious circle" is found in Shanghai transit system

5. A POSSIBLE IMPROVEMENT

In fact, a lot can be done to improve the current transit network operation in collaboration with the experienced transit planners. The possible actions for such improvements are:

1. Network "optimization" to be suggested by NETSYT-I, a computer system developed for transit network optimization at the Shanghai Institute of Mechanical Engineering.
2. Grid-type network.
3. A network with more bus lines having lower frequencies.
4. Long distance line network.
5. Local changes of a bus line in terms of its running direction and frequencies.
6. Introduction of a new bus line.
7. A combination of the above actions, etc.

Our intention is to provide a strong modification of a bus line in order to gain a better service. From the above analysis, we understand that there is a critical situation due to the impact of the "vicious circle" where more passengers are required to pass through the downtown area and Bund in GB5, resulting in a congested area. Consequently, our goal is to improve this situation by finding a proper bus line so that more passengers are expected to be attracted to the line which hopefully will reduce the congestion in GB5.

The original bus line 21 is removed and a new bus line 21 is added, which starts at the intersection of Juan Gong Rd. and Ping Liang Rd., i.e. the node 673 in GB8, and trvels along Ping Liang Rd., Dong Dai Ming Rd., Tian Dong Rd., He Nan Rd., Bejing Rd., Zhang Shuo Rd., Hen Shan Rd., until Xu Jia Hui at node 445 in GB6, as shown in Figure 5.1.

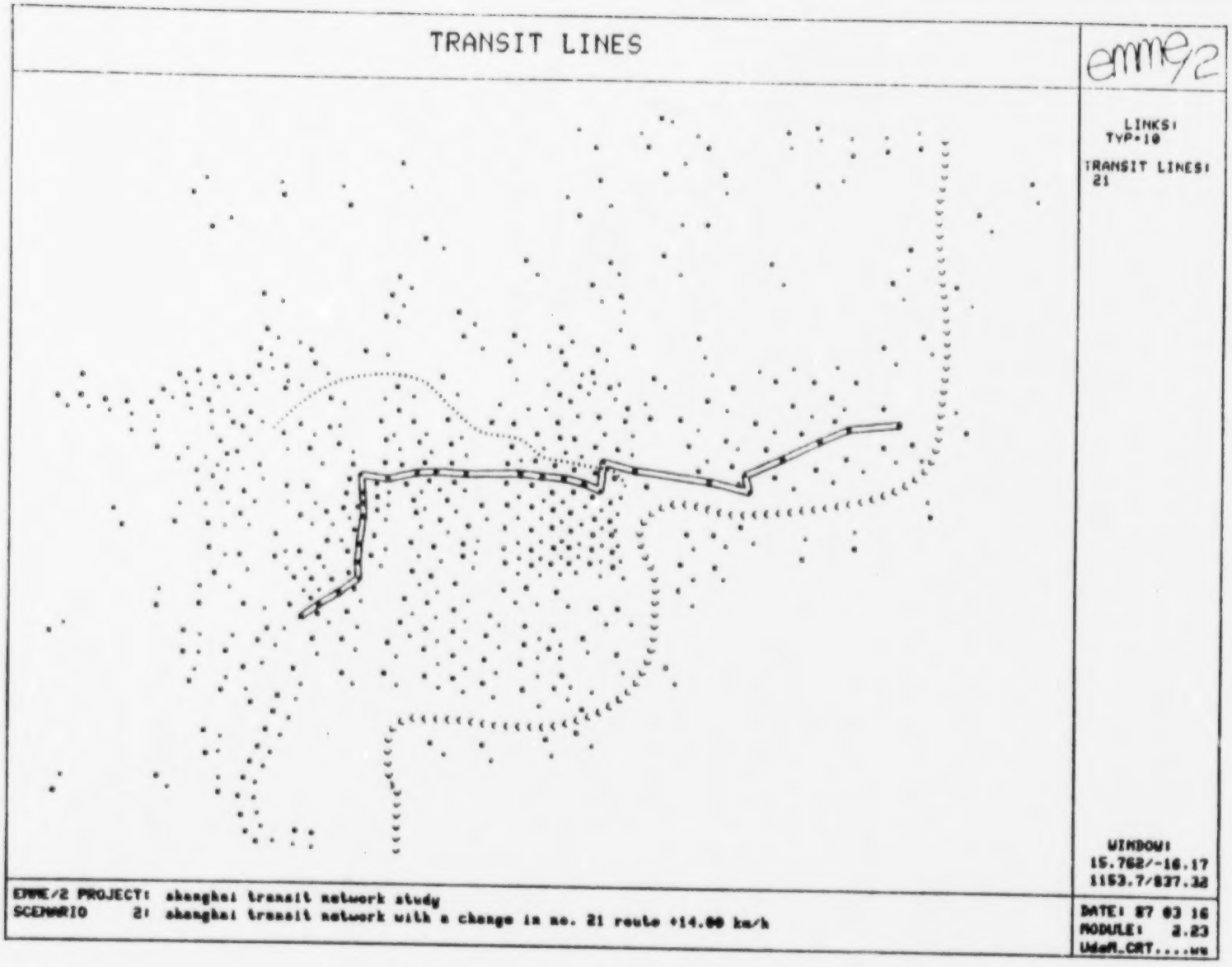

Figure 5.1 : A new bus line 21

For a logical analysis, two speeds are set for the bus line. There is an optimistic one, which is 20 km/h and a pessimistic one of 14 km/h.

Scenario 1 is defined as the current transit system, while Scenario 2 is the improvement system. Through the simulation, we get the following good results which includes some important statistics of the total network, as shown in Table 5.1. Statistics are listed for GB6 and GB8 in Table 5.2.

Table 5.1 : Simulation for these two scenarios on total network

	Scenario 1	Scenario 2	
	Current transit network	Optimistic	Pessimistic
Average number of transfers	1,16	1,16	1,15
Generalized cost	151,82	150,83	150,72
Average transit time	51,42	50,21	50,87
In-vehicle	38,66	37,36	38,10
Walk	6,70	6,73	6,73
Wait	2,59	2,64	2,58
Board	3,47	3,48	3,46

Table 5.2 : Simulation for these two scenarios in GB6 and GB8

	Scenario 1	Scenario 2	
	Current transit network	Optimistic	Pessimistic
Average transit time	50,23	46,17	49,72
In-vehicle	35,38	31,31	35,07
Walk	6,65	6,63	6,63
Wait	2,07	2,19	2,02
Board	6,13	6,04	6,01

For the optimistic speed, the generalized cost and transit time are reduced for the total network, particularly for the travels between GB6 and GB8. There are also many passenger flows to be attracted from bus lines in the downtown area such as GB5 and Bund to the new bus line 21 which does not go through the Bund but only on the outskirts of GB5. This can be seen in Figure 5.2 where a relative difference in terms of passenger flows is displayed between Scenarios 1 and 2. Because of this change, there is about 30% or more reduction in passenger flows for the area GB5 (see Figure 5.3).

Let us examine the transfer nodes in the Bund area in Figure 5.4 where the transfer nodes and the corresponding transfers occurring are displayed in Scenario 1, and for Scenario 2, see Figure 5.5. A high percentage of reductions in transfers is expected.

For the pessimistic speed, we still get better results in the reduction of a little transfer and transit time. Look at the passenger flow in some streets in GB5 shown in Figure 5.6, and the transfers in nodes in GB5 shown in Figure 5.7. We can conclude that there still exists some improvements in the transit network, even though the advantages from the pessimistic one is not as great as the optimistic one.

We can summarize that, based on the current trip pattern and transit network, it is preferable to add a new bus line 21 with the removal of the old line 21. The simulated results indicate that there is not only quite an improvement in the transit service, but there also is a significant reduction in congestion in the downtown area, thus providing a better traffic conditions for that specific area.

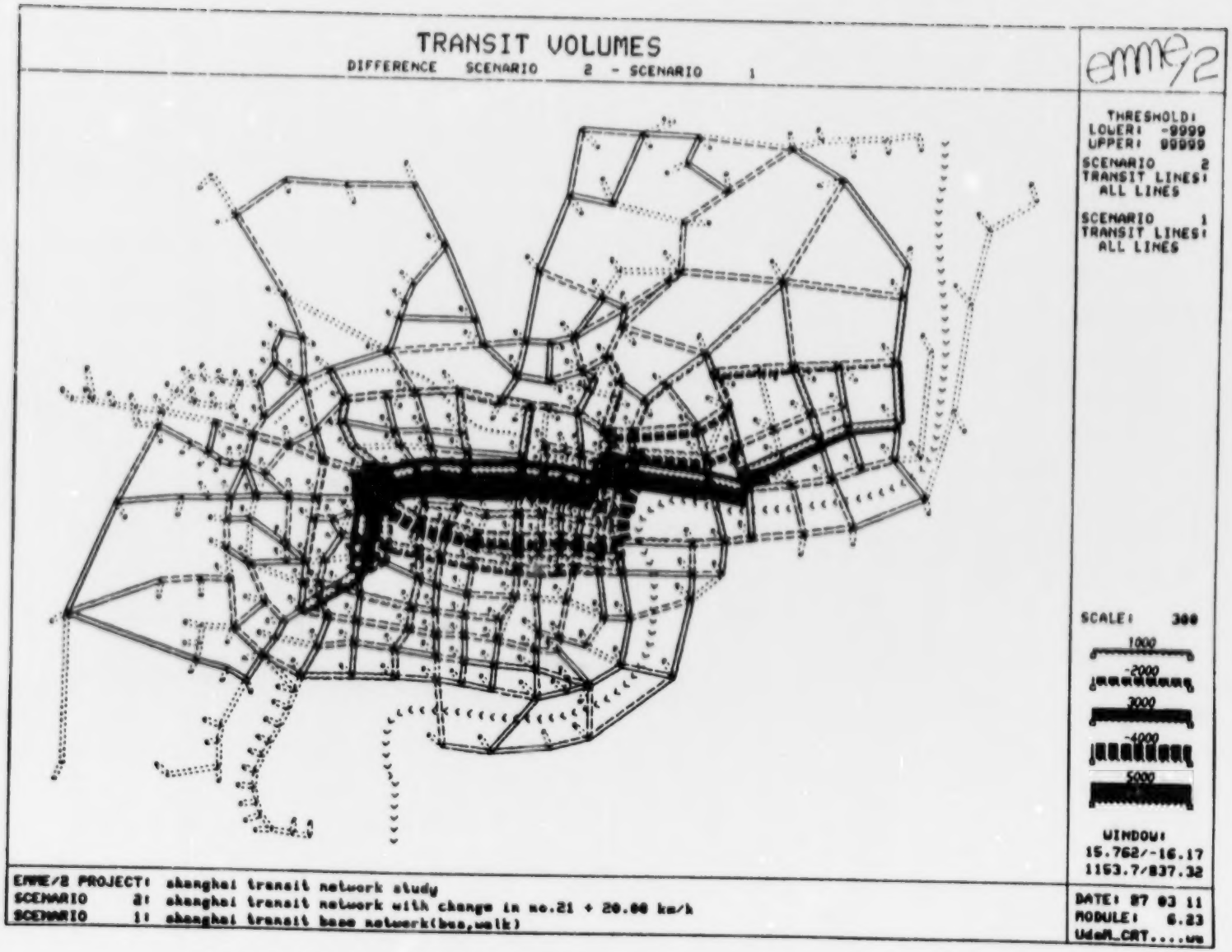

Figure 5.2 : A relative difference in terms of passenger flows between Scenarios 1 and 2 (Optimistic)

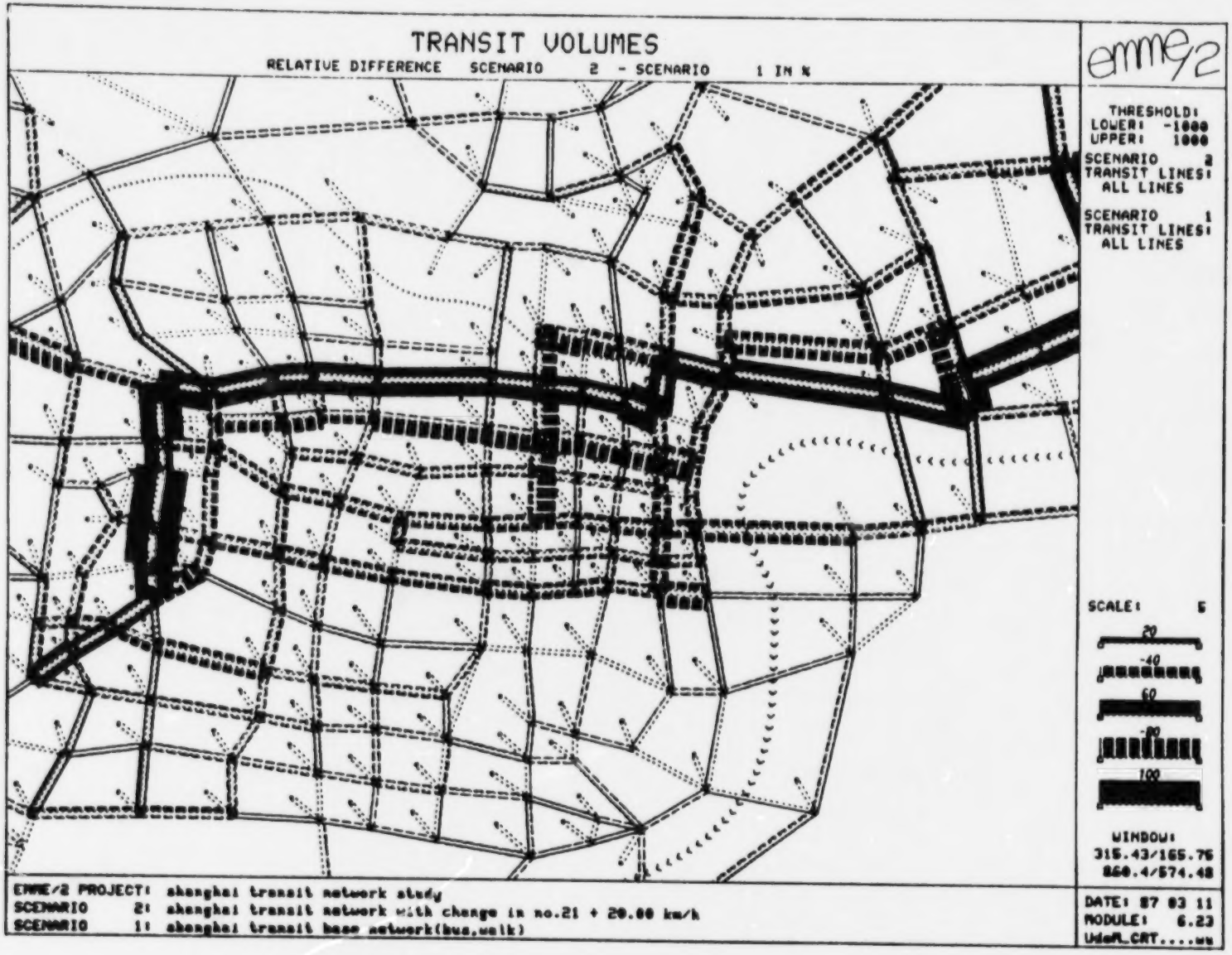

Figure 5.3 : A relative difference in terms of passenger flows between Scenarios 1 and 2 in the downtown area (Optimistic)

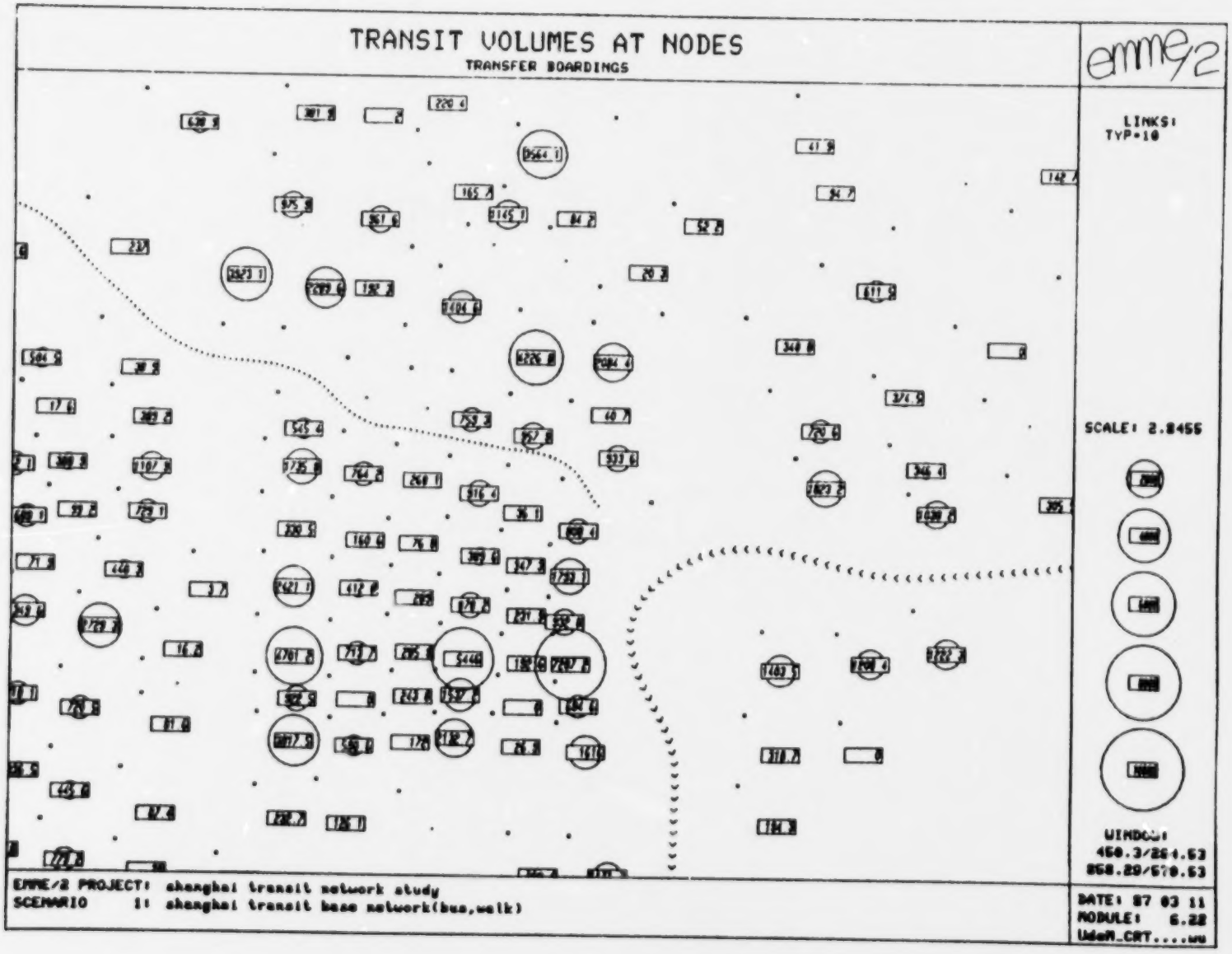

Figure 5.4 : Transfer nodes in the Bund area on the Scenario 1

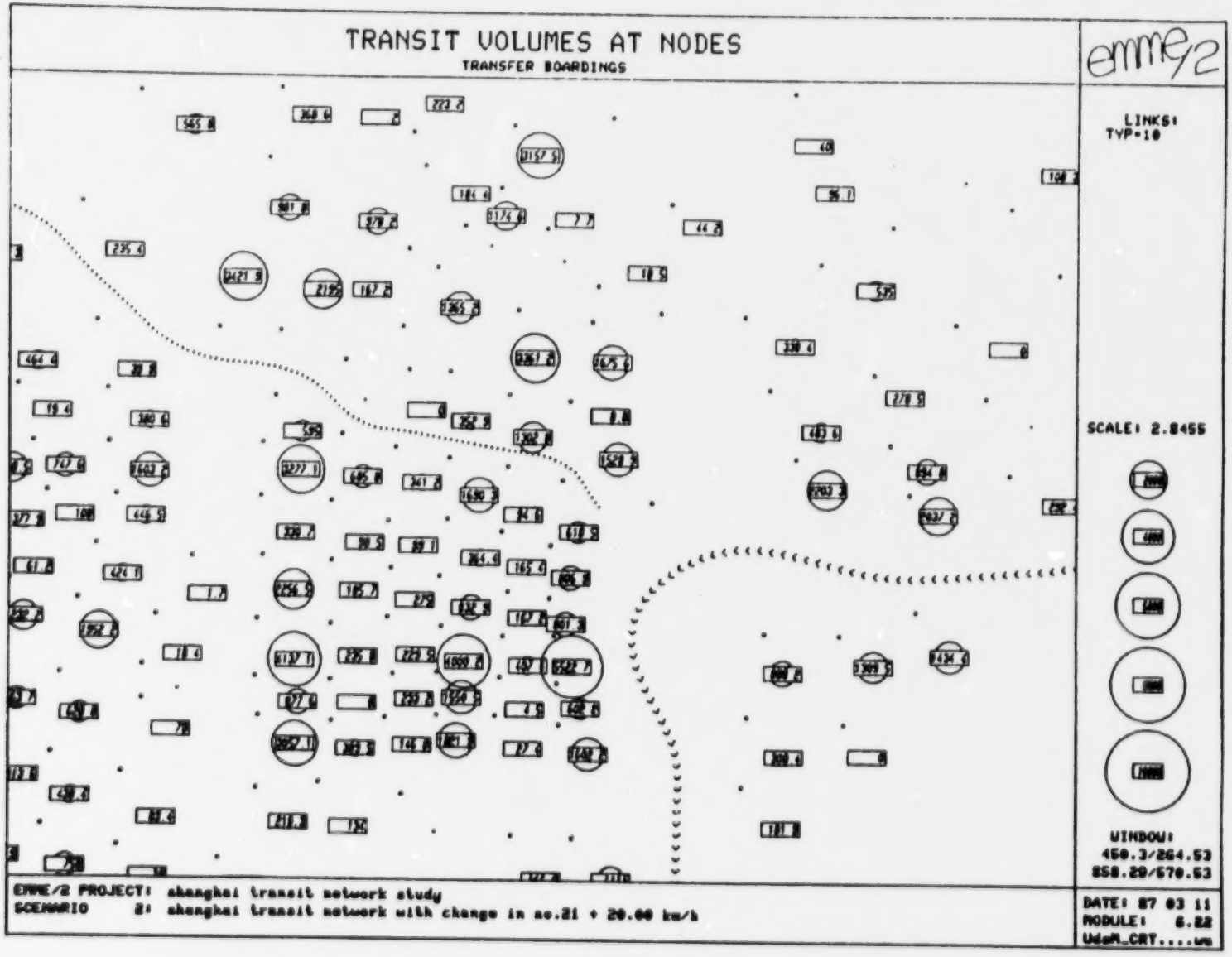

Figure 5.5 : Transfer nodes in the Bund area on the Scenario 2 (Optimistic)

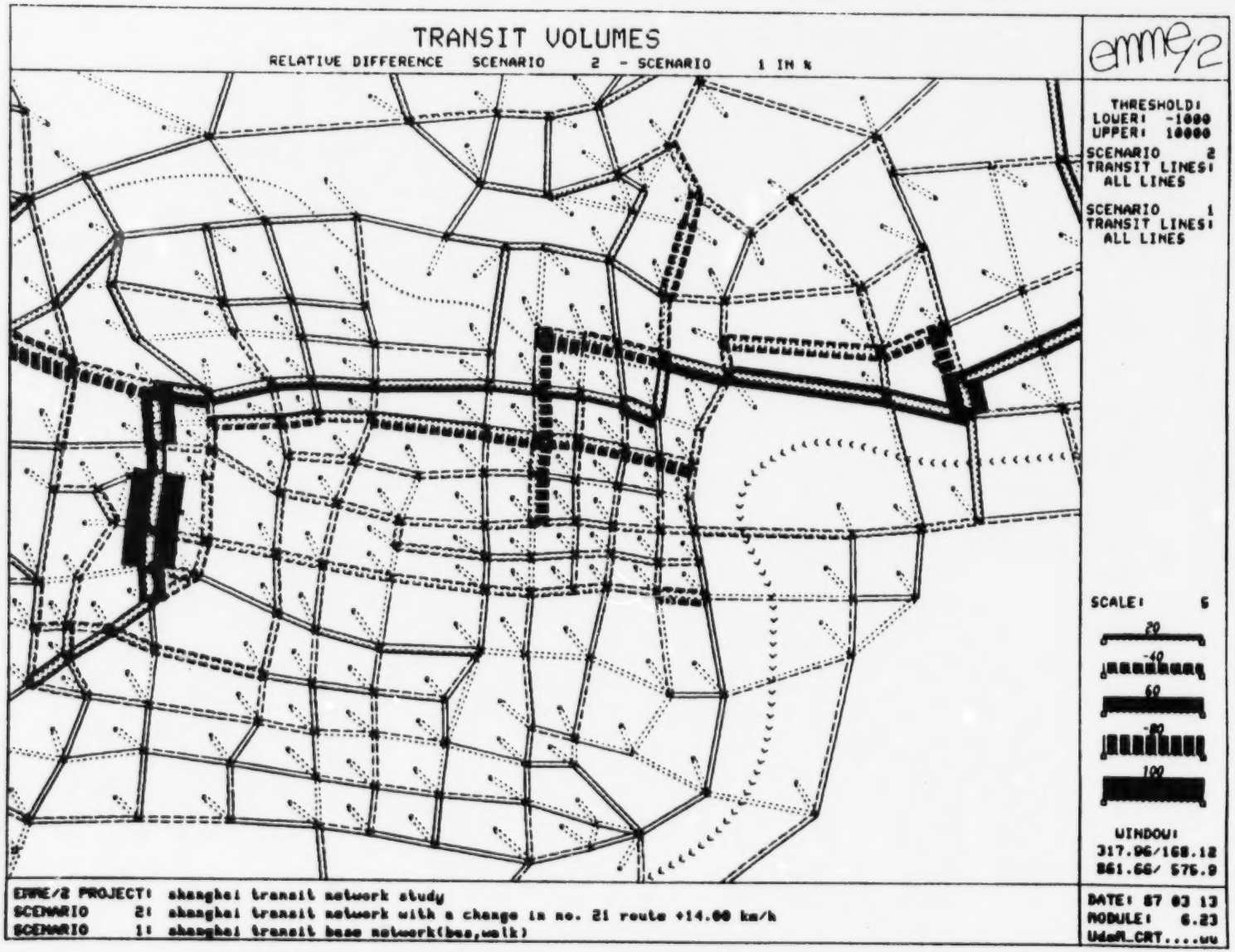

Figure 5.6 : A relative difference in terms of passenger flows between Scenario 1 and 2 in the downtown area (Pessimistic)

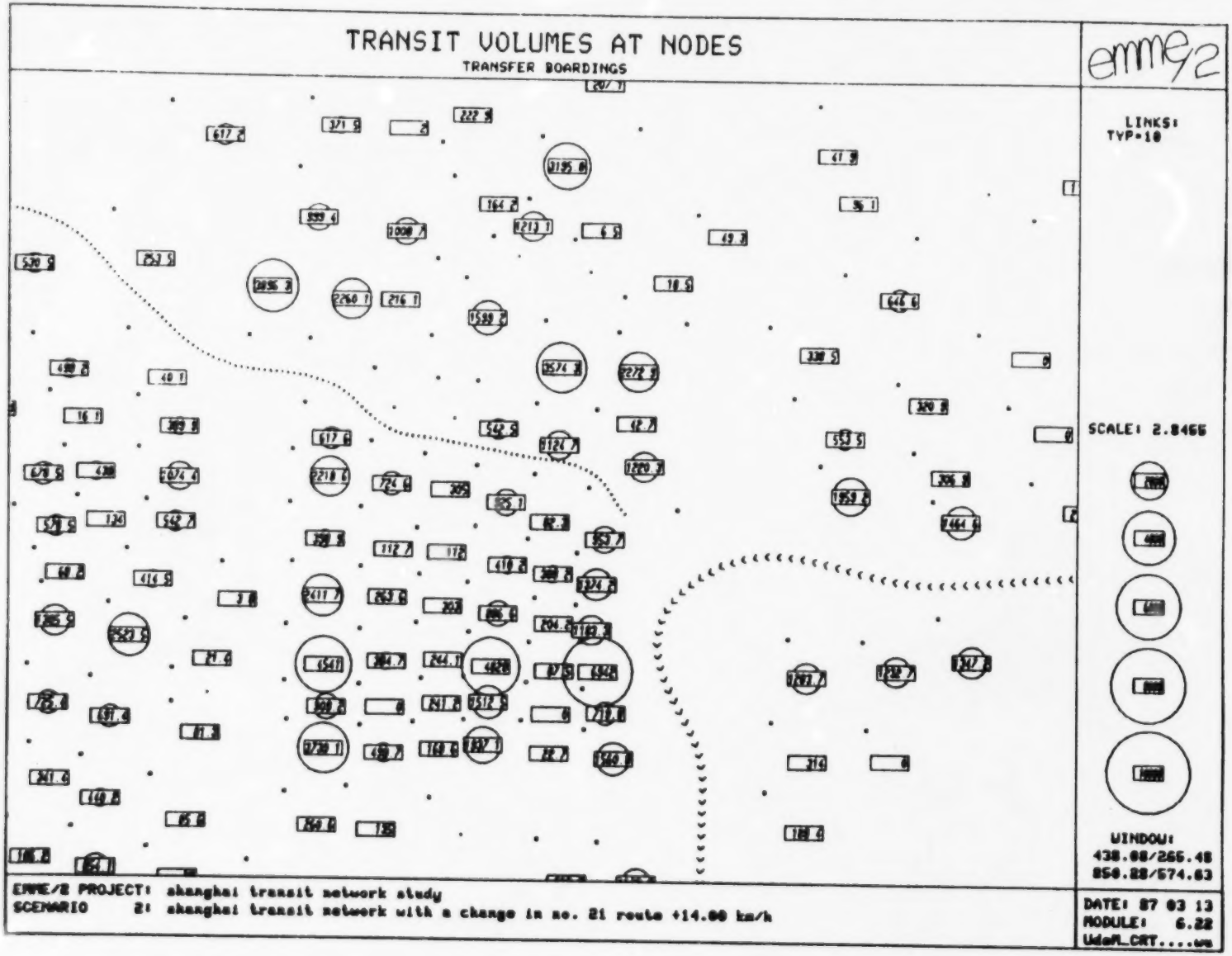

Figure 5.7 : Transfer nodes in the Bund area on the Scenario 2 (Pessimistic)

6. CONCLUSION

In this paper, we used the EMME/2 as a model for the Shanghai transit system based on the Monthly Ticket Survey conducted in 1982. A detailed analysis was carried out in order to understand the transit OD trip pattern and transit structure as well as their influence on the travel pattern. A conventional transit planning method generated a "vicious circle", which resulted in a congestion in GB5. An alternative solution for improving the situation was presented resulting in better transit service and transit congestion conditions.

Based on the preliminary study, it appears to us that there are still great potential areas to explore for the improvement of our transit service in Shanghai. The introduction of the EMME/2 system makes it possible for us to try to solve the problem. It is also highly recognized, that a proper combination of the EMME/2 and NETSYT-I systems would help in the planning of a more efficient transit network in Shanghai.